Vecco Critical Minerals Project

Land-Based Effluent Disposal Assessment Report

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Prepared for:

Vecco Group Pty Ltd c/o AARC Environmental Solutions Pty Ltd

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VECCO CRITICAL MINERALS PROJECT

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1.0 INTRODUCTION

Stantec were commissioned by Vecco Group (c/o AARC Environmental Solutions Pty Ltd) to undertake land-based irrigation modelling for the Vecco Critical Minerals Project (Vecco Project) and produce a Land-Based Disposal Assessment Report.

During the operation phase of the mine, workers will generate sewage from the onsite accommodation and general facilities. The wastewater from these sources will need to be treated and disposed of in a manner which is economical, practical and environmentally sustainable. In this case, the most feasible method will involve a basic level of treatment followed by land-based disposal.

This report summarises the site background and constraints, justifies the chosen land-based disposal method and validates it with the use of the Model for Effluent Disposal Using Land Irrigation (MEDLI) version 2.0.

1.1 BACKGROUND

The site is located within the Northern Highlands of the Queensland Outback, in the McKinlay Shire Council Local Government Area, approximately 70 km north of Julia Creek township and approximately 515 km west of Townsville in northwest Queensland. The townships of Cloncurry and Richmond are located approximately 125 km west and 145 km east of the Project respectively. The proposed Mining Lease Applications (MLAs) for the Vecco Project as provided by AARC are presented in **Figure 1-1**: Location of Proposed Vecco Project (Source: AARC 2023)

The project is currently in the Environmental Authority Application phase, and therefore detailed design/operation information is yet to be developed. At this point in time, the key components of the project include:

- open cut mining of up to 1.9 Mtpa ROM ore over a period of approximately 26 years;
- development of a mine infrastructure area (MIA), including, administration buildings, bathhouse, crib rooms, storage warehouse, workshop, fuel storage, refuelling facilities, wash bay, laydown area, and a helipad;
- development of mine areas (open cut pits) and out-of-pit waste rock emplacements. This includes vegetation and soil stripping;
- development of out-of-pit waste rock emplacements;
- construction and operation of a Mineral Processing Plant (MPP) and ore handling facilities adjacent to the MIA (including ROM ore and product stockpiles and rejects);
- construction of an access road from Punchbowl Road to the MIA;
- construction of an airstrip to provide access for the Royal Flying Doctors Service;
- construction of a 10 MW solar farm and associated energy storage system;
- installation of a raw water supply pumping system and pipeline to connect the MIA to the Saxby River for water harvesting;
- construction of an on-site workers village and associated facilities, including an adjacent sewage treatment plant (STP);
- other associated minor infrastructure, plant, equipment and activities;
- progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required;

- open-cut mining operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers);
- strategic disposal of neutralised process rejects within the backfilled mining void;
- continued exploration and resource definition drilling on the MLAs;
- progressive development of internal roads and haul roads including a causeway over the Saxby River (designed for minimum impact on flow events) to enable access and product haulage;
- development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains; and
- progressive rehabilitation occurring at defined milestones through the operational life. All voids will be backfilled to natural surface, ensuring all rehabilitated landforms achieve a sustainable post-mining land use on closure.

Existing regional infrastructure, facilities and services may be used to support Project activities. These include the Townsville Port, the rail networks, electricity networks, local roads and the Flinders Highway. During operation, domestic wastewater will be generated from the on-site workers village, MIA, and associated facilities. The wastewater will include that which is generated from the use of toilets (often classed as black water) as well as wastewater produced from showers, kitchen facilities and laundry (often classed as grey water). It is important to distinguish this domestic wastewater does not include Mine Water or Sediment Water which will be stored and handled in a separate manner.

1.1.1 Environmental Authority Requirements

The wastewater system at the Vecco Project has the capacity to cater for a maximum of 146 employees (although during standard operation 90 employees are likely to be on site). Given the wastewater system will cater for more than 21 Equivalent Persons (EPs) (1 EP = 200 L/day), the activity triggers Environmental Relevant Activity (ERA) 63 for sewerage treatment. Therefore the EA which is being obtained for mining activities will need to include sewage treatment (ERA 63) as an associated activity.

An application for ERA 63 authority must provide supporting technical information in accordance with the DES *Guideline Application requirements for activities with impacts to land*. These guidelines encourage the applicant to:

Design a sustainable system in accordance with Australian New Zealand Standard *AS/NZS 1547:2012 On-site domestic wastewater management*; and

Undertake validation modelling of the system based on the local land and rainfall factors. The recommended model being the Model for Effluent Disposal using Land Irrigation (MEDLI) Version 2.0.

This report therefore centres around AS/NZS 1547:2012 and validation MEDLI 2.0 modelling of the irrigation site at the Vecco Project.

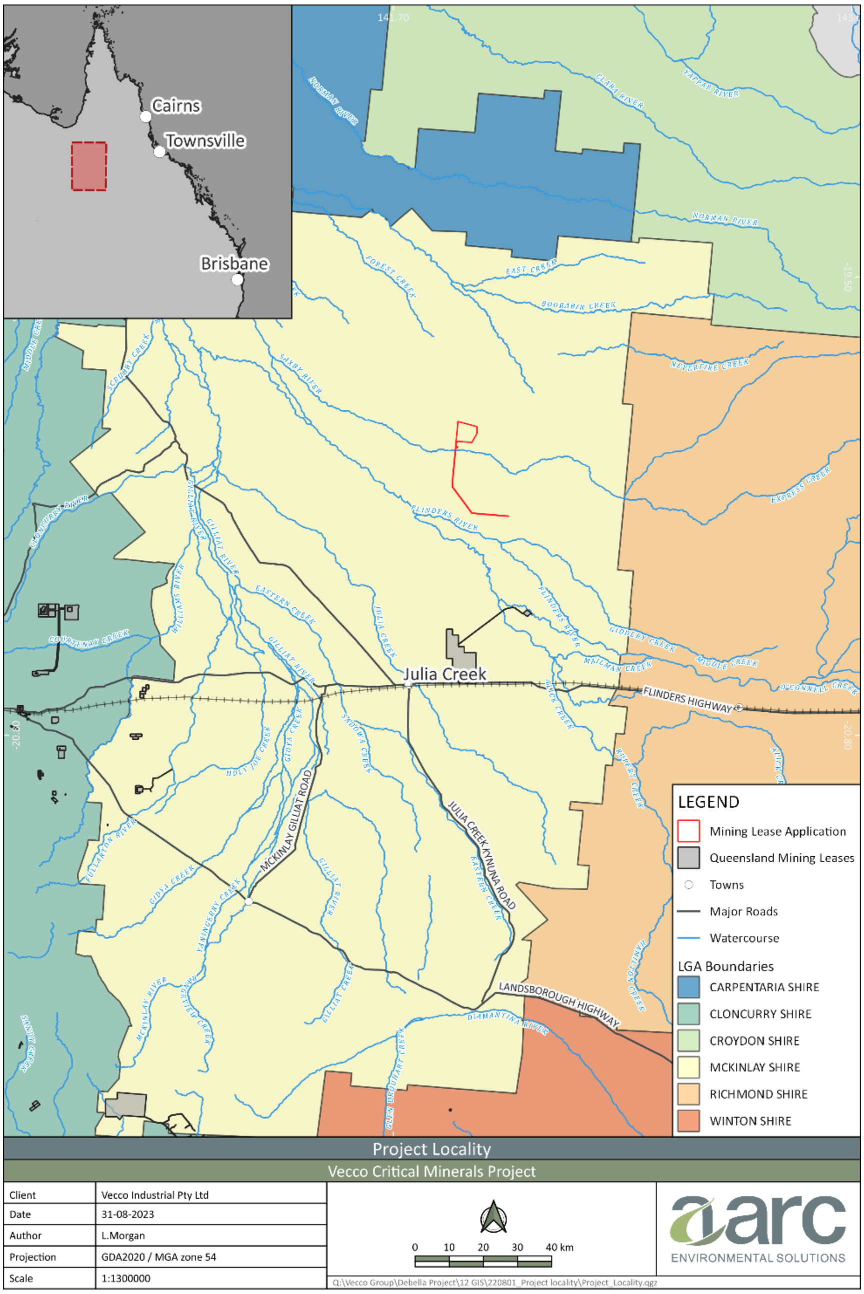


Figure 1-1: Location of Proposed Vecco Project (Source: AARC 2023)

2.0 AIM OF ASSESSMENT

2.1 OBJECTIVES

The principal objectives of the assessment are to:

Ensure that the land-based disposal system applies treated effluent over a suitable area, at a suitable rate to ensure that effluent does not run off, cause waterlogging, or cause high levels of nutrient leaching into the subsoil;

Ensure that the water balance is correctly predicted to ensure that treated effluent storage tanks/ponds do not frequently overflow; and

Ensure that sensitive receivers are not overly exposed to health risks from the disposal system (i.e. ensuring treatment and exposure reduction methods are sufficient to minimise pathogen exposure).

2.2 SCOPE OF WORK

The scope of this assessment is limited to assessing the suitability of land areas within the Vecco Project site for effluent disposal via irrigation. The assessment consisted of:

A desktop review of site topography, hydrology and soil type to select the most suitable effluent disposal area;

Using AS1547: 2012 to estimate the irrigation rate and layout using soil condition assumptions obtained during the review;

Given that it will not be possible to provide site specific soil data into the MEDLI model, the two most extreme soil types will be modelled, and a system can be designed to cater for either set of conditions:

- Model A: MEDLI 2.0 default Heavy Clay model – to test the irrigation systems ability to cope with highly impermeable soil.
- Model B: MEDLI 2.0 default Sand model – to test the irrigation systems ability to cope with highly permeable soil.

Mitchell SMU soil details and chemical properties are provided in Sections 5.1 and 5.2 of the AARC Soil Surveys report.

Calculating expected wastewater quality and generation rates for the site;

Obtaining site-specific climate data for the region (particularly rainfall/evaporation rates);

Verifying the suitability of the subsurface irrigation system using software issued by DES: the Model for Effluent Disposal through Land Irrigation (MEDLI); and

Providing recommendations to improve the performance of the irrigation system.

As agreed with AARC, Stantec’s assessment was limited to a desktop assessment only, including a review of general soil data previously obtained by AARC. This report also does not include provision for a Site Based Management Plan applicable to the ongoing operation of a wastewater disposal system. Prior to commissioning the treatment plant and disposal system, a Site Based Management Plan detailing ongoing maintenance requirements, emergency response and contingency procedures will be required.

2.3 FUNDAMENTALS OF MEDLI

Irrigation modelling systems offer a way of validating and refining irrigation systems designed in accordance with AS 1547:2012. Daily time step simulation models such as the Model for Effluent Irrigation using Land Disposal (MEDLI) Version 2.0 are generally considered a requirement by DES in order to obtain an ERA 63 EA.

2.3.1 MEDLI 2.0 Background

MEDLI Version 2.0 is a modelling program that simulates the complex dynamics of the effluent cycle on a daily time step, using historical daily climatic data. MEDLI 2.0 simulates the behaviour of water and nutrients in the soil column and the growth of irrigated pastures or crops in response to climatic conditions and nutrient and salt loadings. MEDLI 2.0 can be used to determine the required irrigation area, likely stresses on irrigated vegetation and the concentration of nutrients and salt in groundwater for given conditions. The model is based on historic climate information (temperature, rainfall, evaporation, and solar radiation), estimates of the effluent quality and quantity, and soil and groundwater properties. Modelling is designed to provide an overview of the proposed environmental impacts and to identify any significant areas of concern that may require further detailed investigations. Actual findings will depend on detailed information with respect to geology of the soils and groundwater, proposed irrigation methods and management practices in the field.

The effluent modelling process enables the identification of limitations in the wastewater disposal scheme, providing the opportunity to explore alternative solutions until a suitable and robust design is found. By using MEDLI 2.0 in the feasibility process, effluent disposal essentially becomes a transparent issue, enabling safety in its design.

2.3.2 Modelling Objectives

A successful model will generally have the following outcomes:

- Wet weather storage tank overflow events will be negligible in frequency and volume.
- 90% reuse (irrigation) of effluent should occur (99.5% re-use is ideal);
- No overflow events which equate to more than the top 1mm of the tank should occur; and
- Overflow should be experienced less than 10 days per year;
- No surface runoff of irrigated effluent should occur;
- Less than 5kg/ha/year of nitrate is to be lost in deep drainage;
- Greater than 30 years of phosphorus adsorption capacity available in the soil;
- Build-up of salinity in the soil profile should not impede on the growth success of the grass; and
- Any pasture die-offs resulting from water stress, waterlogging, temperature stress or nitrogen stress are to be minimised as close to zero as possible.

3.0 DESKTOP ASSESSMENT

3.1 PREFERRED IRRIGATION LOCATION

At this point in time it is assumed that all sources of domestic wastewater from the accommodation facilities and MIA will be channelled to a single treatment plant and the treated effluent piped to an irrigation area.

The proposed irrigation area being investigated for treated effluent disposal is located approximately 700 m north of the accommodation village and STP area and approximately 1000m south of the Mine Infrastructure Area (MIA) (**Figure 3-1**). This area is being investigated because:

It is within close proximity to the primary source of wastewater (the proposed mine accommodation village), therefore minimising pumping requirements;

It is at similar elevation to the primary source of wastewater (accommodation facilities), therefore minimising pumping requirements;

It will be highly accessible from the proposed access road; and

There is sufficient space to allow for placement of disposal area and still maintain large buffers from sensitive receivers such as waterways, sensitive ecosystems, the accommodation village, the MIA and the mine itself.

3.1.1 Flood Immunity

A review of the McKinlay Shire Planning Scheme Map indicates there is a Queensland Flood Assessment Overlay (QFAO) (Saxby River) approximately 4 km south from the investigation area and approximately 2 km south from the greater proposed MLA area. The QFAO was developed for use by local governments as a potential flood hazard area and represents an estimate of areas potentially at threat of inundation by flooding. Given that irrigation investigation area is a significant distance away from the QFAO it is not subjected to flooding.

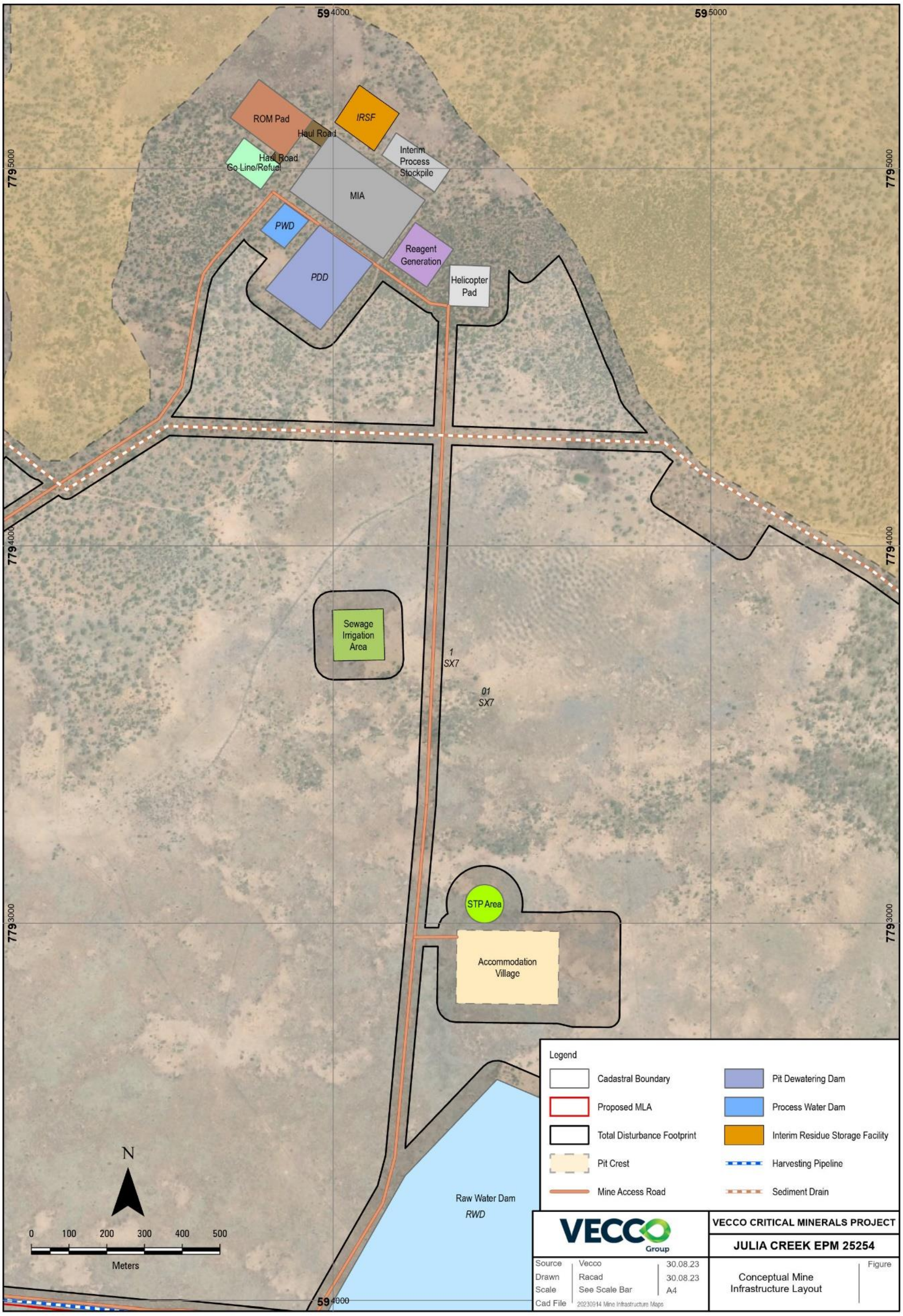
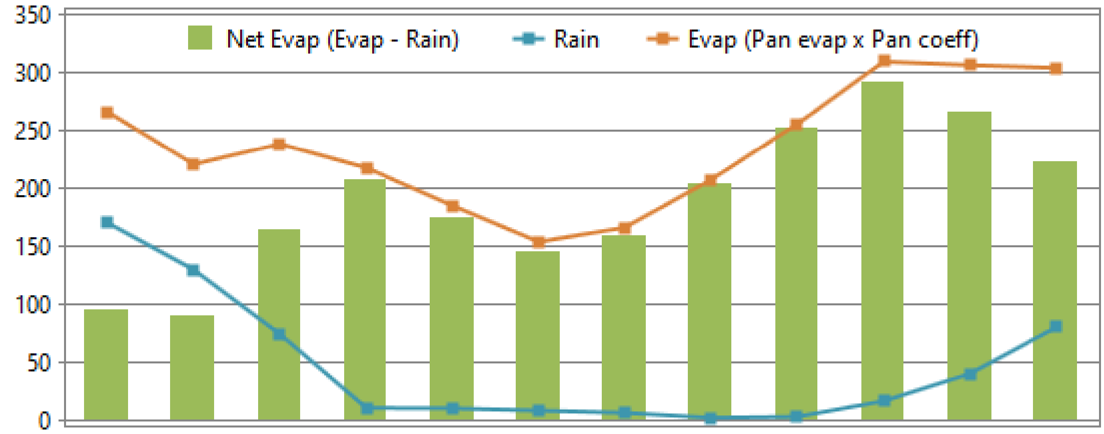


Figure 3-1: Sewage Irrigation Investigation Area

3.2 CLIMATE

Climate data was obtained from the Queensland Government Scientific Information for Land Owners (SILO) at the closest grid point -19.95 141.90. SILO interpolates the data from the nearest climate stations. The data includes evaporation rates, rainfall and maximum and minimum temperatures for a period of 53 years from 1970 to 2022.

The site has a relatively dry climate, with evaporation rates exceeding rainfall throughout the year. A distinctive dry/wet season pattern is observed, whereby the winter period from April to September almost no rainfall occurs, with higher rainfall (typically from storms) received over the summer months from September to January. Even during the wet season, the evaporation rates still far exceed rainfall rates. The data has been summarised below in **Figure 3-2**.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	171.1	130.6	75.1	11.6	11.3	9.4	7.4	3.2	4.1	17.5	41.0	81.0	563.2
Evap	266.9	221.6	239.0	218.6	185.9	154.6	167.0	208.1	256.3	310.2	307.2	304.8	2840.3
Net Evap	95.8	91.0	163.9	207.0	174.6	145.3	159.6	205.0	252.1	292.8	266.2	223.9	2277.1
Net Evap/day	3.1	3.2	5.3	6.9	5.6	4.8	5.1	6.6	8.4	9.4	8.9	7.2	6.2

Figure 3-2: Climate Data for the site 1970 – 2022

Topography, Drainage and Groundwater

The irrigation investigation area is in a near flat location, with an elevation of approximately 130m Australian Height Datum (AHD). A slight gradient falls from a northeast to south direction. The investigation area does not contain any drainage lines of significance. Saxby River is located approximately 2km south of the MLAs. The reasonably flat nature and distance from significant watercourses is ideal for effluent irrigation.

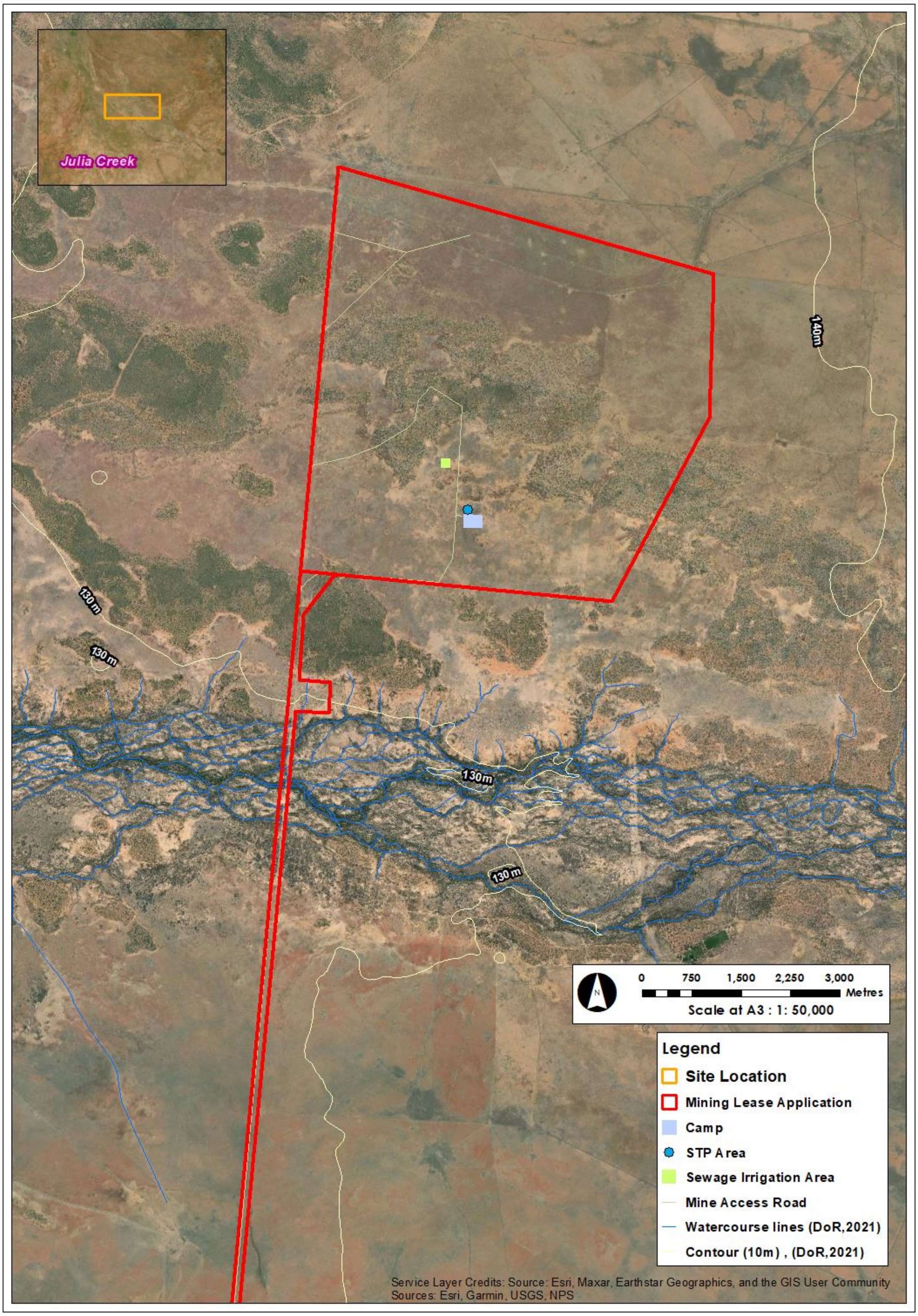


Figure 3-3: Topography and drainage of site and surrounds

A regional groundwater table is likely to be present at significant depth given that the site is quite elevated. A nearby registered bore (RN69643) indicates that the regional groundwater table is present at approximately 27m below ground level as of the last measurement in September 1990.

3.3 ONSITE VEGETATION

The area being investigated for irrigation does not contain tall standing vegetation or any endangered or of concern regional ecosystems. In accordance with the Queensland Regional Ecosystem (RE) mapping, the irrigation investigation area is located within least concern RE 2.4.2 Tussock Grassland on Tertiary Clay deposits.

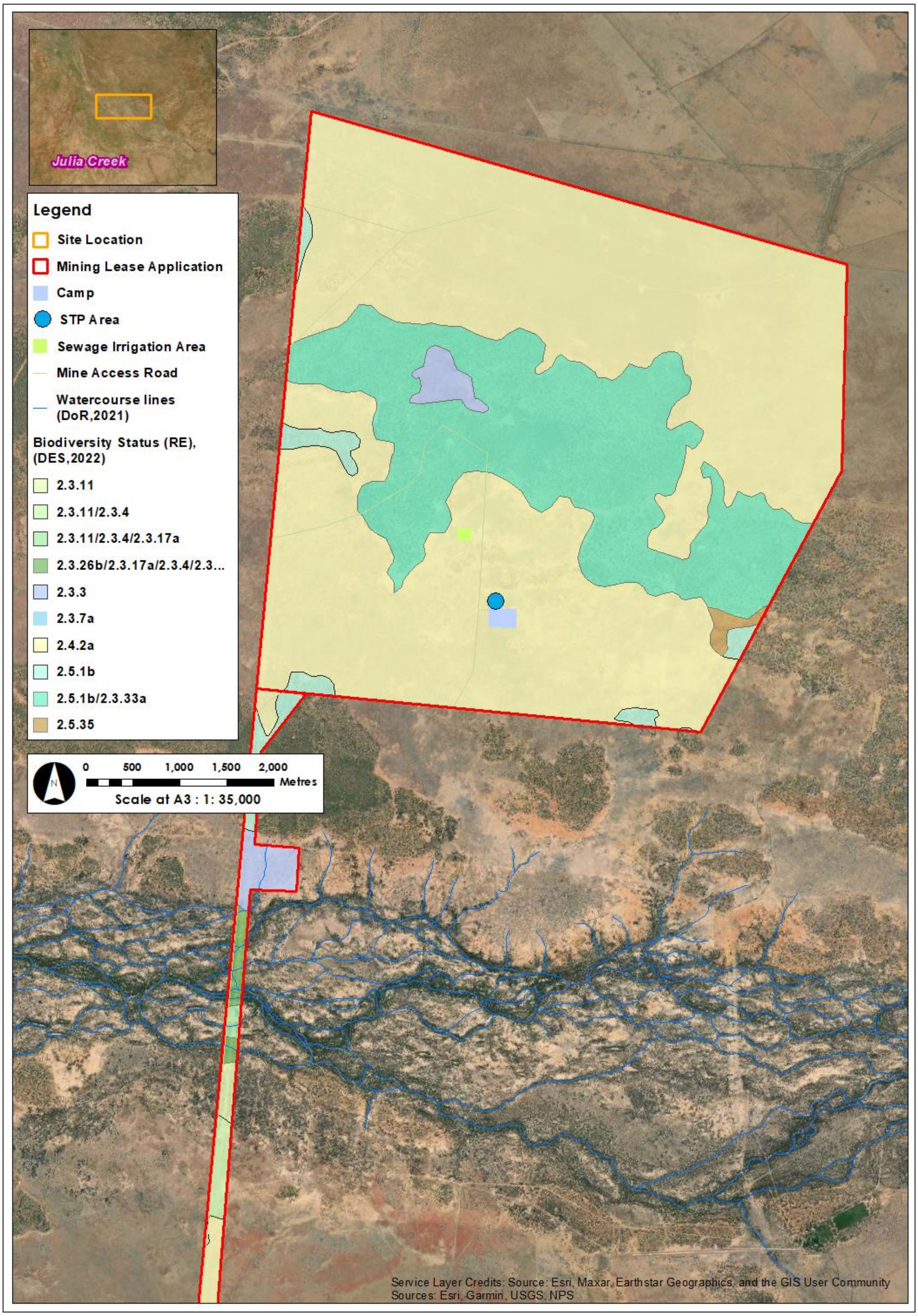


Figure 3-4: Proximity of irrigation area to adjacent Regional Ecosystems

3.4 SENSITIVE RECEPTORS

Aside from the sensitive natural environmental receivers outlined above, other sensitive receptors include residents/workers at the mine. The irrigation investigation area is located approximately 770m north of the proposed accommodation facilities and approximately 1045m south of the MIA. At such large distances, workers using the MIA or accommodation will not be affected by any spray aerosols.

In respect to the main access road, the irrigation area will need to be managed via appropriate level of treatment and exposure reduction (i.e., irrigation area restriction, set back distances etc) to minimise any aerosol or odour exposure to those using the access road.

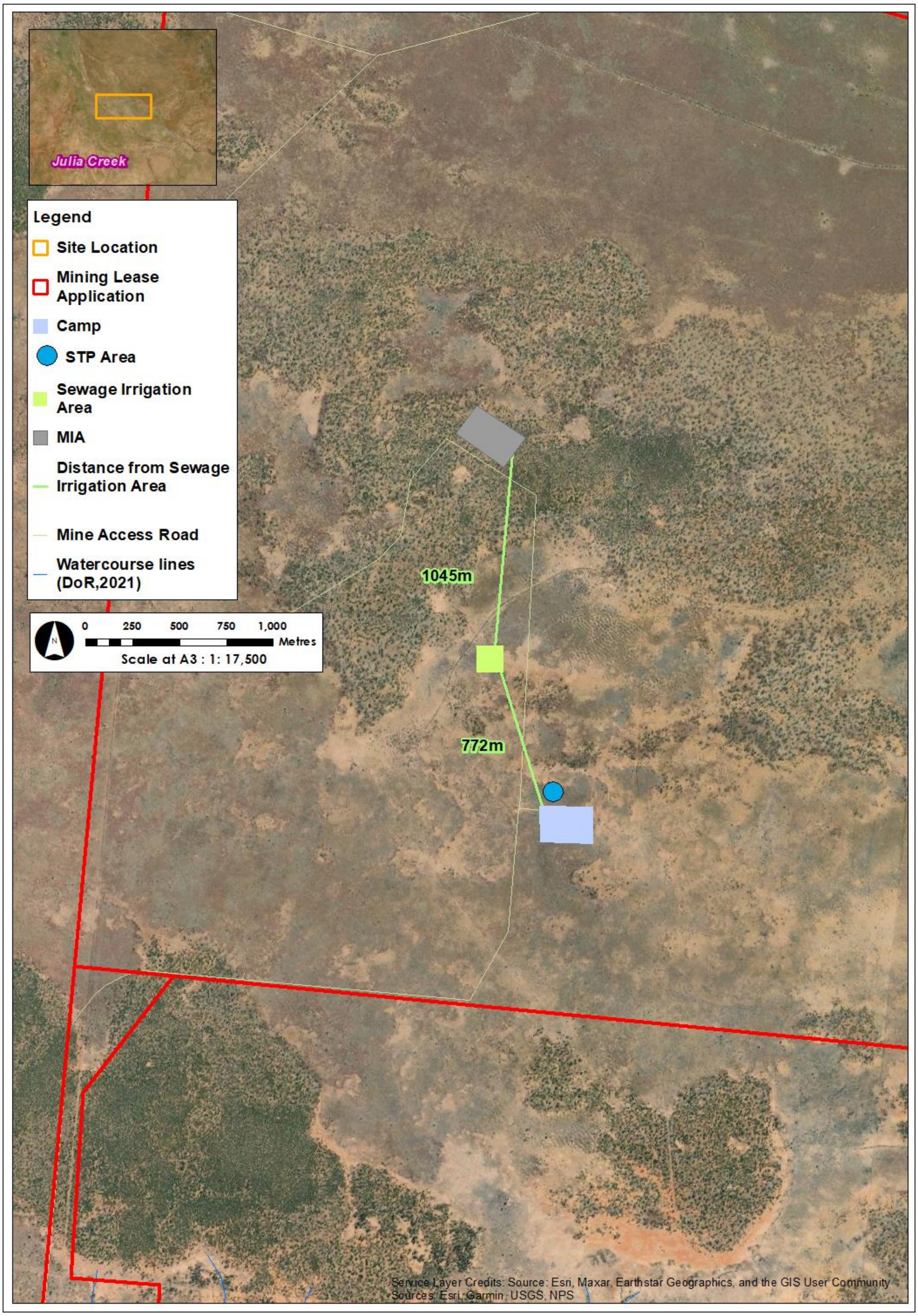


Figure 3-5: Irrigation Investigation Area in respect to proposed accommodation facilities

4.0 DESCRIPTION OF WASTEWATER

Given that the mine and any associated infrastructure/accommodation facilities have yet to be established, the wastewater quantity and quality had to be conservatively estimated as per the following subsections.

4.1 WASTEWATER QUANTITY

The wastewater system at the Vecco Project has the capacity to cater for a maximum of 146 employees although during standard operation 90 employees are more likely to be on site.

For the purpose of this exercise, it has been conservatively estimated that all 146 workers will be on site, and each worker will generate the entire wastewater volume that equates to 1 equivalent person (EP).

The *Environmental Protection Regulation 2019* states that 1 EP = 200 L/day of effluent. With a total of 146 EPs the total daily wastewater volume is conservatively estimated at **29,200 L/day**.

4.2 WASTEWATER QUALITY

As the design of the mine and associated infrastructure progresses the most feasible/practical treatment plant will be decided upon, and from there the expected effluent quality can be more accurately determined. The following subsections provide a conservative estimate of the effluent quality.

4.2.1 Key Contaminants

In the absence of specific information, conservative estimates have been provided in **Table 4-1**. These have been based on the long-term limits established in the *Eligibility Criteria and Standard Conditions for Sewage Treatment Works (ERA 63) – Version 2*. These limits also align with the quality which would be expected from a basic sewage treatment plant as per *Table A3.2 of the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)*.

Table 4-1: Wastewater Quality Estimations: Source ERA 63 Eligibility Criteria Standard Conditions

Quality Characteristics	Release Limit	Limit Type
Total nitrogen	30 mg/L	Maximum
Total phosphorus	10 mg/L	Maximum
Electrical conductivity	1600 µs/cm	Maximum
pH	5.0 – 8.5	Range
Total residual chlorine (if used for disinfection)	1 mg/L	Maximum
E. coli	<1000 cfu/100mL	Maximum

4.2.2 Other Contaminants

In addition to the above parameters, Australian New Zealand Standard 1547:2012 recommends that a secondary treated effluent is achieved for irrigation systems as per **Table 4-2**. These limits are primarily for operational purposes (i.e., to avoid clogging up pipes/fittings and soil pore spaces with solids and biofilms).

Table 4-2: Wastewater Quality Estimates – Secondary Treated Effluent: Source AS/NZ 1547

Quality Characteristics	Release Limit	Limit Type
Total Suspended Solids	20 mg/L	Maximum
Biochemical Oxygen Demand	30 mg/L	Maximum

5.0 IRRIGATION AREA SOIL DESCRIPTION

At this point in time the investigation area cannot be accessed to obtain site specific soil samples, therefore the soil conditions need to be estimated based on the *AARC Vecco Critical Minerals Project Soil and Land Suitability Assessment* (2023).This was a soil assessment for the greater mining lease site which describes and maps land suitability classes of the proposed mine area.

In summary, the irrigation investigation area is within the Soil Management Unit (SMU) defined as the Mitchell SMU which covers approximately 3/4 of the mine lease (refer to **Figure 5-2**). The following sections are extracted from the *AARC Vecco Critical Minerals Project Soil and Land Suitability Assessment*(2023).

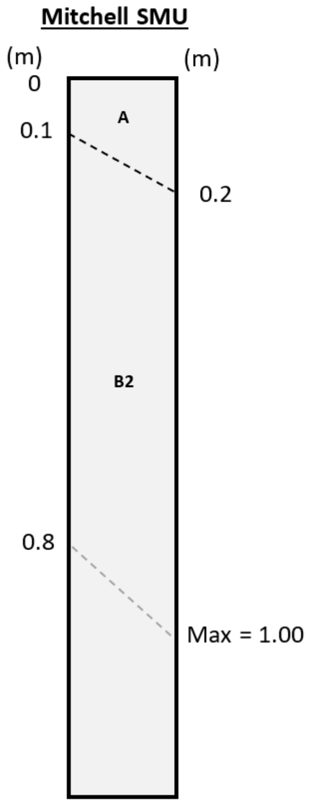
5.1 SOIL MANAGEMENT UNIT DESCRIPTION

The Mitchell SMU consists of predominantly Grey Dermosols with Grey Vertosols occurring on gently inclined or near-level plains within an old alluvial landscape. This SMU is distributed throughout the majority of Study Area (i.e. the area that was the subject of the *AARC Vecco Critical Minerals Project Soil and Land Suitability Assessment*) as regions of palaeo-drainage and flood channels. The soil consists either of a sandy surface, or self-mulching sandy clay surface, with clay content increasing with depth. Vegetation is predominantly Feathertop Wiregrass and Mitchell Grass Tussock Grassland as per **Figure 5-1**. (AARC, 2023). For further soil details refer to **Table 5-1**.

Figure 5-1: Mitchell SMU Landscape and Land Surface

Table 5-1: Mitchell SMU Soil Details

Mitchell SMU	
Area / % total	2302 ha / 73%
Observation sites	VO2, VO4, VO5, VO14, VO11, VO12, VO14, VO15, VO16, VO17, VO19, VO20, VO21, VO22, VO23, VO25,VO27, VO28, VO29, VO32, VO33, VO34, VO35, VO38, VO39
Sample sites	VP4, VP6, VP10, VP11, VP12, VP15
ASC	Vertosol; Dermosol
Land System	Balbirini
Geology	Wondoola Beds (TQw)
Vegetation	Feathertop wiregrass, with silky browntop, Astrebla spp. and Eragrostis spp. tussock grassland. Shrub layer dominated by whitewood and the environmental weed mimosa bush. The tree layer is almost entirely absent, though there is the occasional emergent whitewood and beefwood.
Landform	Plains.
Slope	0 – 1 %
Surface condition	Firm, minor surface cracking with surface crusting, occasionally self-mulching, 40% ground cover with occurrence of minor surface microrelief (normal/linear gilgai).
Runoff	Slow.
Permeability	Moderately permeable.
Drainage	Well drained.



SOIL PROFILE DESCRIPTION

Horizon	
A	*Light brownish grey (10 YR 6/2), sandy loam to sandy clay loam, pH 7 – 7 ½, massive and granular or 10 – 20 mm weak and angular blocky, no mottles or segregations*
B2	*Greyish brown (10 YR 5/2), medium clay, pH 8 – 8 ½, 20 – 50 mm angular block/subangular blocky, no mottles or segregations*

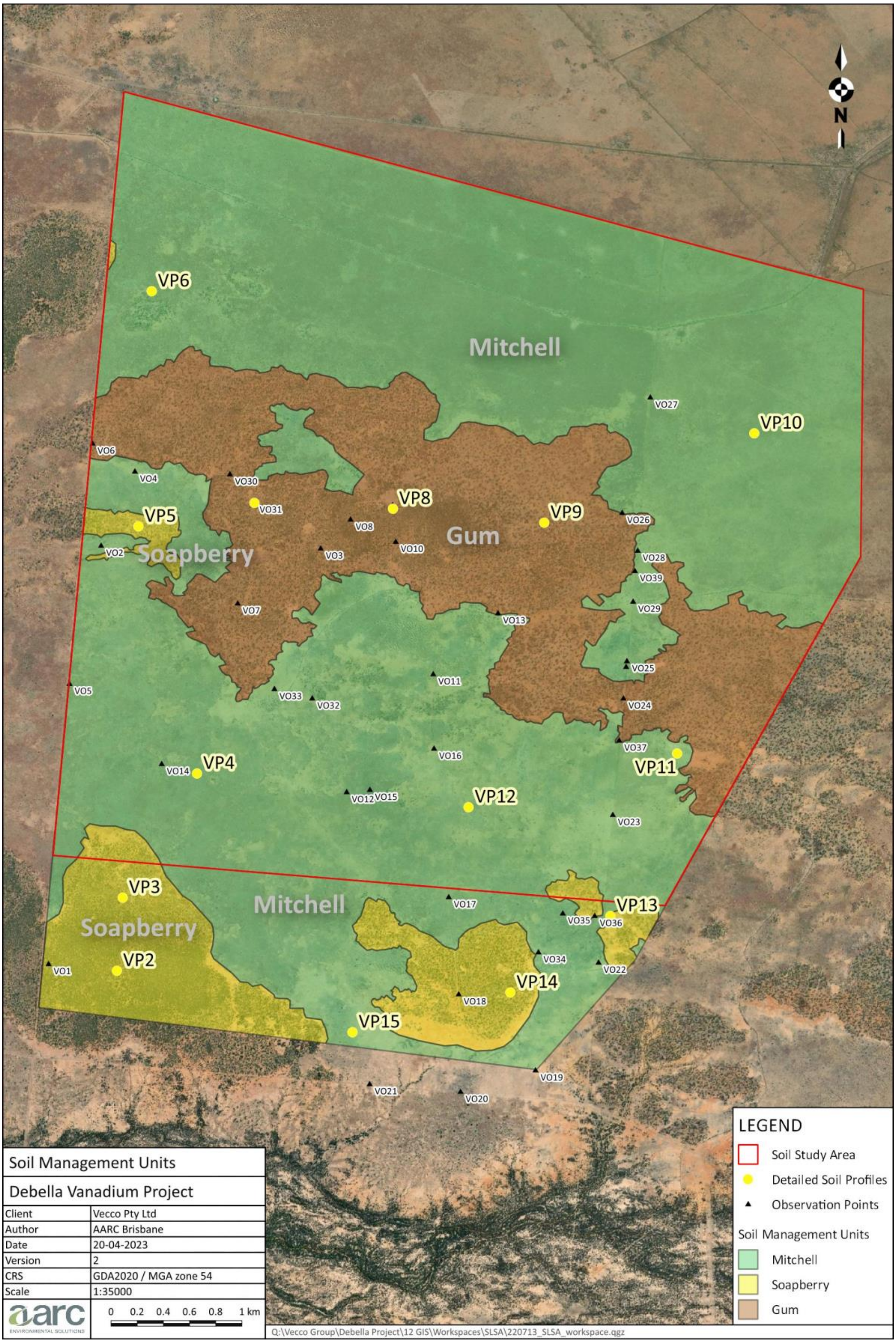


Figure 5-2: Distribution of Soil Management Units

5.2 CHEMICAL AND PHYSICAL ANALYSIS

The neutral pH in the upper soil profile of the Mitchell SMU is within a suitable range for plant growth; it is not expected to limit the availability of essential nutrients above 0.5 m depth.

Electro-conductivity (EC_{SAT}) values and chloride concentrations are considered low, this SMU is not affected by issues associated with salinity and toxic chloride concentrations (Rayment and Lyons 2011).

Cation exchange capacity (CEC levels) for this SMU is considered low to medium throughout the profile (11.4 – 13.8 milliequivalents (meq)/100 g). The medium CEC levels still can allow moderate to high availability of nutrients in the topsoil, with all exchangeable cations within levels ideal for plant growth.

Non-sodic conditions occur in the top 0.3 m of the profile, observed as a low ESP levels. However, subsoils from 0.5 m are expected to display sodic properties, demonstrated by increased pH and concentration of free sodium in subsoil (ESP 7 – 13). This is further supported by Emerson class 2 at 0.5 m depth observed at some profile sampling sites (VP4 and VP11), which indicates slaking with some dispersion of aggregates. (AARC, 2023)

Table 5-2: Chemical Properties of the Mitchell SMU. Representative Site VP12. Source – AARC 2023

Depth (m)	pH	EC_{SAT} (dS/m)	Cl (mg/kg)	ESP (%)
0 – 0.1	7.0	0.124	<10	1.1
0.2 – 0.3	8.5	0.220	< 10	1.9
0.5 – 0.6	9.0	0.480	< 10	6.8
0.7 – 0.8	9.2	0.765	20	13.1

Depth (m)	CEC (meq/100 g)	Exchangeable cations (meq/100 g)				Ca/Mg Ratio	Emerson test class
		Ca	Mg	K	Na		
0 – 0.1	11.4	7.5	3.2	0.3	0.1	2.3	3
0.2 – 0.3	13.8	11.9	1.6	< 0.2	0.3	7.4	4
0.5 – 0.6	13.0	10.5	1.6	< 0.2	0.9	6.7	3
0.7 – 0.8	12.5	9.1	1.8	< 0.2	1.6	5.1	2
Nutrient distribution in topsoil (%)		67.6	28.8	2.7	0.9	-	-

Topsoil typically displays weak-to-moderate structure, due to dominant sand fraction (55%) with lesser clay (29%). Risk of dispersion and erosion in the surface layer is considered low, although organic matter content is considered very low.

Extractable nutrients are considered poorly balanced with both low phosphorus and nitrate concentrations (Hazelton and Murphy 2016). Sulphate in the topsoil is considered marginal while potassium content is above suitable concentrations.

Extractable metals were mostly present at ideal concentrations, except boron with concentrations below ideal range.

Table 5-3: Surface Soil (0-10cm) properties of the Mitchell SMU. Source AARC 2023

Particle Size Analysis (%)				Soil Particle Density (g/cm^3)	Organic Matter (%)
Clay	Silt	Sand	Gravel		
29	13	55	3	2.65	0.7

Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorus	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	256	< 10	1.2	< 0.2	< 1	13.0	8.16	< 1

6.0 DESKTOP AS1547 ASSESSMENT

6.1 SELECTION CRITERIA

To determine the suitability of a site/system for spray irrigation, a comparison against Appendix K of AS 1547:2012 has been presented in Table 6-1 on the following page. Overall, it can be seen that the nature of the soil and the site is generally supportive of spray irrigation, although the sodicity in the lower soil profile will need to be managed to ensure the soil does not become dispersive.

Table 6-1: Selection Criteria for Irrigation Systems (Appendix K or AS/NZS 1547:2012)

	Slope Gradient	Soil Depth	Soil Category Number	Depth to seasonal water table	Duration of continuous seasonal soil saturation	Dispersive (sodic) soil	High content of stones, cobbles, or boulders	Climatic factors
Recommendation	Steep slopes can cause greater run-off during wet weather (< 10%).	A minimum of 0.6 m desirable.	Categories 1 and 2 may lead to nutrients reaching groundwater. Categories 4-6 may require large irrigation fields.	>1.2 m depth.	Prolonged saturation of upper soil impedes treatment and hinders adsorption.	Sodic soil may lose permeability during life of system.	Unless extremely stony or covered in boulders, not relevant as delivery pipes need not be dug in soil in straight line.	Best in climates where intense rainfall events are uncommon and evapotranspiration exceeds rainfall in most months.
Conditions apparent on site	Site near flat	Soil profile >1 m deep.	Category 5-6 (clay based)	Groundwater approx. 25-30 m below ground.	Saturation generally not an issue given the dry climate	Sodicity present in the subsoil	Gravel and stone not observed in nearby soil samples	Climate suitable. Net evapotranspiration far exceeds rainfall year-round.

6.2 DESIGN CRITERIA

The following sections provide design criteria for standard surface spray irrigation systems in accordance with Appendix L and Appendix M of AS 1547:2012.

6.2.1 Irrigation Trigger

Irrigation schemes can be scheduled using either a soil moisture deficit standard, or a set daily irrigation rate.

A soil moisture trigger allows for large volumes to be irrigated in dry conditions (i.e. much of the winter dry season), but minimal or no irrigation can occur during wet conditions (i.e. frequent periods in the summer wet season). The use of a soil moisture trigger requires large wet weather storage volumes but can lessen the irrigation area required.

A set daily irrigation rate provides the same daily irrigation rate which will take place despite weather conditions. Given that irrigation will occur every day, minimal wet weather storage is required (it is generally reserved only for truly waterlogged/flooded days). The disadvantage of a set daily irrigation rate is that the rate needs to be kept quite low, so as to not overload the soil profile in the wetter months. This typically results in the need for a larger irrigation area than would be required for a soil moisture trigger scheme.

The site has a moisture deficit throughout the majority of the year (evaporation exceeds rainfall), there is unlikely to be a major difference in irrigation area between a moisture deficit or a set irrigation scheme. Given that a set irrigation rate scheme requires minimal wet weather storage requirements and is simpler to operate, a set irrigation scheme was considered to be warranted for this site.

6.2.2 Design Irrigation Rate

AS 1547:2012 assumes a secondary treated effluent will be irrigated (BOD 20 mg/L & TSS 30 mg/L). AS 1547:2012 uses this quality assumption to deem a suitable irrigation rate based on soil permeability.

The limiting soil profile is the subsoil which is likely to consist of a heavy clay. In a heavy clay (category 6 soil) AS 1547:2012 recommends an irrigation rate no higher than 2mm day.

The 2mm/day rate was set as a daily maximum within the MEDLI model. The MEDLI model was then used to test how the soil/plant responded. In some cases, the daily maximum can be raised if the model responds well. In this case the maximum rate remained at 2mm/day, and this is discussed in further detail in Section 7.

7.0 MEDLI MODELLING

Typically, a MEDLI model will be based on site specific soil data. In the absence of site-specific soil data, the advice from the Queensland Government MEDLI team was to produce extreme soil scenario models in order to undertake a sensitivity analysis. The two most extreme models are:

An extremely permeable soil (sand). Sandy soils are susceptible to nutrient leaching below the root zone if they are irrigated too intensely.

An extremely impermeable soil (clay). Clay soils are susceptible to waterlogging. This results in surface runoff, and in addition to this, a waterlogged profile allows for nutrient leaching below the root zone.

7.1 A NOTE ON PASTURE TYPE

Typically, Rhodes Grass would be modelled owing to the fact it is well suited for the climate conditions and has a strong demand for nutrients. Rhodes Grass is also one of the default grass types available in the MEDLI 2.0 model. AARC have indicated that DES have a preference that Rhodes Grass is not used in mine revegetation. Instead of a Rhodes Grass pasture, the irrigation area will therefore likely consist of the existing Mitchell Grass which covers the local area. Given that Mitchell Grass is not available in the MEDLI 2.0 model, the model had to assume Rhodes Grass.

7.2 EXTREME IMPERMEABLE SCENARIO

The simulation was carried out from 1970 – 2022. Daily climate information for -19.95, 141.90 (including rainfall, pan evaporation, maximum and minimum temperatures and solar radiation) was obtained from the SILO database.

The key model inputs were as per Table 7-1.

Table 7-1: Extreme Impermeable MEDLI Input Parameters

Parameter	Proposed System
Effluent quantity	29.2 m^3/day
Wet Weather Storage Tank Volume/Capacity	88 m^3 (3 days)
Tank System Sludge Accumulation	0.0 kg dwt/year
Average Rainfall	536.2 mm/yr
Soil Evaporation	2840.3 mm/yr
Effluent Irrigation Area	1.8 ha
Irrigation Application	Daily maximum of 2mm depth
Total Nitrogen entering the tank system	30 mg/L
Total Phosphorous entering the tank system	10 mg/L
Salinity	1600 µs/cm
Pasture Type	Rhodes Grass (although in practice the surrounding native Mitchell Grass is likely to cover the irrigation area)
Soil Type – Extreme Impermeable Model	Default MEDLI 2.0 Grey Clay
Wet Weather Infiltration into Network	Zero (due to new and confined network)

7.2.1 Hydraulic Balance Results

The modelling outputs indicated that by using the above irrigation scheme 100% of the treated effluent could be reused (irrigated) with no overflow events occurring.

7.2.2 Nutrient Balance Results

Nitrogen (N)

The nitrogen balance indicated that the average load of nitrogen added to the soil was 177.75 kg/ha/year. The average load of nitrogen removed by plant uptake was 236.75 kg/ha/year. This indicates there was a net average removal of nitrogen from the irrigation area. As is naturally expected, there are still a limited number of occasions when more nitrogen is added than removed (i.e. heavy rain periods), and during those occasions some nitrate is leached into the groundwater table. On average 0.21 kg/ha/year of nitrate would leach via deep drainage. This is well within the accepted limit of 5 kg/ha/year.

Phosphorous (P)

The phosphorus balance indicated that the average load of phosphorus added to the soil was 59.25 kg/ha/year. The average load of phosphorus removed by plant uptake was 51.85 kg/ha/year. This indicates a slight net average addition of phosphorus to the irrigation area. This is typically expected as most plants have a demand for nitrogen which far exceeds the demand for phosphorus.

Given that a small net addition of phosphorus occurs in most land based effluent disposal systems, the soil phosphorus adsorption capacity is relied on. It is generally considered acceptable if the phosphorus adsorption capacity life reaches 30 years or more. The model confirmed that the above scenario can achieve 44.94 years life capacity.

Salinity

Modelling using Rhodes Grass (considered to be moderately salt-tolerant) indicated the resulting salinity would be too low to impact upon the health of the grass. Grass health is important to maintain to ensure that nitrogen and phosphorus uptake is maximised.

7.2.3 Waterlogging

This model is limited by waterlogging as clay soils have limited permeability. By spreading out the effluent over an area of 1.8 ha and a maximum daily irrigation rate of 2mm/day, waterlogging was entirely eliminated. When irrigation occurs more intensively than this, the model starts to display signs of waterlogging in particularly wet years (i.e. 1974, 2011)

7.2.4 Surface Runoff Water Quality

In a similar fashion to waterlogging, the model is subject to effluent runoff if effluent is irrigated any more intensely than 2mm/day maximum over 1.8ha.

It must be noted that the model cannot account for site specific conditions such as any rainwater ponding or run-on. Once an irrigation area has been established, it must be designed to ensure that pooling does not occur, and run-on from any uphill areas is diverted around the irrigation area.

7.2.5 Model Summary

The MEDLI 2.0 model supports the irrigation of effluent in a clay soil over 1.8 ha at no more than 2mm/day. If the soil is irrigated any more intensely than this, it is prone to waterlogging and runoff.

For further detail, the extreme impermeable MEDLI output report is provided in **Appendix A**.

7.3 EXTREME PERMEABLE SCENARIO

The simulation was carried out from 1970 – 2022. Daily climate information for -19.95, 141.90 (including rainfall, pan evaporation, maximum and minimum temperatures and solar radiation) was obtained from the SILO database.

The key model inputs were as per Table 7-2.

Table 7-2: Mine Construction Period Extreme Permeable MEDLI Input Parameters

Parameter	Proposed System
Effluent quantity	29.2 m^3/day
Wet Weather Storage Tank Volume/Capacity	88 m^3 (3 days)
Tank System Sludge Accumulation	0.0 kg dwt/year
Average Rainfall	536.2 mm/yr
Soil Evaporation	2840.3 mm/yr
Effluent Irrigation Area	1.5 ha
Irrigation Application	Daily maximum of 2mm depth
Total Nitrogen entering the tank system	30 mg/L
Total Phosphorous entering the tank system	10 mg/L
Salinity	1600 µs/cm
Pasture Type	Rhodes Grass (although in practice the surrounding native Mitchell Grass is likely to cover the irrigation area)
Soil Type – Extreme Impermeable Model	Default MEDLI 2.0 Sand
Wet Weather Infiltration into Network	Zero (due to new and confined network)

7.3.1 Hydraulic Balance Results

The modelling outputs indicated that by using the above irrigation scheme 100% of the treated effluent could be reused (irrigated) with no overflow events occurring.

7.3.2 Nutrient Balance Results

Nitrogen (N)

The nitrogen balance indicated that the average load of nitrogen added to the soil was 213.30 kg/ha/year. The average load of nitrogen removed by plant uptake was 241.97 kg/ha/year. This indicates there was a slight net average removal of nitrogen from the irrigation area. As is naturally expected, there are still a limited number of occasions when more nitrogen is added than removed (i.e. heavy rain periods), and during those occasions some nitrate is leached into the groundwater table. On average 1.1 kg/ha/year of nitrate would leach via deep drainage. This is well within the accepted limit of 5 kg/ha/year.

Phosphorous (P)

The phosphorus balance indicated that the average load of phosphorus added to the soil was 71.10 kg/ha/year. The average load of phosphorus removed by plant uptake was 57.41 kg/ha/year. This indicates a slight net average addition of phosphorus to the irrigation area. This is typically expected as most plants have a demand for nitrogen which far exceeds demand for phosphorus.

Given that a small net addition of phosphorus occurs in most land based effluent disposal systems, the soil phosphorus adsorption capacity is relied on. It is generally considered acceptable if the phosphorus adsorption capacity life reaches 30 years or more. The model confirmed that the above scenario can achieve 30.16 years life capacity.

Salinity

Modelling using Rhodes Grass (considered to be moderately salt tolerant) indicated the resulting salinity would be too low to impact upon the health of the grass. Grass health is important to maintain to ensure that nitrogen and phosphorus uptake is maximised.

7.3.3 Surface Runoff Water Quality

The model indicated no surface runoff of the irrigated effluent would occur. However, the model cannot account for site specific conditions such as any rainwater ponding or run-on. Once an irrigation area has been established, it must be designed to ensure that pooling does not occur, and run-on from any uphill areas is diverted around the irrigation area.

7.3.4 Model Summary

The MEDLI 2.0 model supports the irrigation of effluent in a sand soil over 1.5 ha at no more than 2mm/day. If the soil is irrigated any more intensely than this, it is prone to overwhelming the soil phosphorus adsorption capacity. For further detail, the MEDLI output report is provided in **Appendix B**.

8.0 AEROSOLS, PATHOGENS, ODOUR AND TOXINS

8.1 AEROSOLS AND PATHOGENS

A spray irrigation system will likely be the most simple and practical method of irrigation for this site. Spray irrigation systems disperse effluent through the air, which can result in fine mist, otherwise termed as aerosols. The aerosols can contain pathogens which can be carried for some distance on the wind.

There are a range of measures which can be put into effect to minimise the exposure risk to the public and staff from exposure to aerosols. The *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* contain guidance based on achieving pathogen hazard log reduction targets. If these hazard reduction targets can be achieved for the given scenario, the human health risk is considered to be negligible. The appropriate targets for a municipal system such as this have been extracted and presented below in **Table 8-1** below. The reduction targets are as follows:

Viruses – 5.0 log reductions.

Protozoa – 3.5 log reductions.

Bacteria – 4.0 log reductions.

Hazard log reduction targets can be achieved via treatment alone, or in combination with exposure reduction measures. These are discussed in further detail in **Section 8.1** and **Section 8.2.**

Table 8-1: Pathogen hazard log reduction targets for priority uses of recycled water from treated sewage (Source – National Guidelines for Water Recycling)

Activity	Route of exposure	Exposure (litres) x freq (per year)	Log reduction *Cryptosporidium*	*Rotavirus*	*Campylobacter*
Commercial food crops	Ingestion – Lettuce – Other produce **Total**	0.005 x 70 0.001 x 140 **0.49**	**4.8**	**6.1**	**5.0**
		Dual reticulation			
Garden irrigation	Ingestion of sprays Ingestion – Low – High **Total**	0.0001 x 90 0.001 x 90 0.1 x 1 0.2	**4.4**	**5.8**	**4.6**
Garden food crops	Ingestion – Lettuce – Other produce **Total**	0.005 x 7 0.001 x 50 0.09	**4.0**	**5.3**	**4.2**

Activity	Route of exposure	Exposure (litres) x freq (per year)	Log reduction *Cryptosporidium*	*Rotavirus*	*Campylobacter*
Internal uses					
Toilet flushing	Ingestion of sprays	0.00001 x 1100	3.1	4.5	3.3
Washing machine	Ingestion of sprays	0.00001 x 100	2.1	3.5	2.3
Cross-connections	Ingestion	1 x 0.365	4.7	6.1	4.8
Total internal use (no garden use)		0.38	4.7	6.1	4.8
Total residential use (garden + internal)		0.67	4.9	6.3	5.1
Municipal Irrigation	Ingestion of sprays	0.001 x 50	3.7	5.2	4.0
Dual reticulation plus municipal irrigation	Ingestion water and sprays	0.72	5.0	6.4	5.1
Fire fighting	Ingestion water and sprays	0.02 x 50	5.1	6.5	5.3

Log reduction calculations:

Cryptosporidium = Log (number of organisms in sewage x exposure (L) x frequency / 1.6 x 10^{-2})

Rotavirus = Log (number of organisms in sewage x exposure (L) x frequency / 2.5 x 10^{-3})

Campylobacter = Log (number of organisms in sewage x exposure (?) x frequency / 3.8 x 10^{-2})

8.1.1 Treatment Pathogen Log Reductions

Hazard log reductions can be achieved by using various treatment processes, either singly or in combination. Section 3.4.2 of the *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* provides detail on the log reductions which can be achieved via various treatment technology.

8.1.2 Exposure Pathogen Log Reductions

Hazard log reductions can be achieved by using various exposure control processes, either singly or in combination. Section 3.4.3 of the *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* provides detail on the log reductions which can be achieved using various exposure control measures.

8.1.3 Recommended Combination of Treatment and Exposure Reduction

The *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* provide examples of how log reductions using treatment (Section 9.2) and exposure control (Section 9.3) can be achieved. The three examples which are relative to municipal irrigation are provided below in **Table 8-2**. The options are presented in order of highest level of treatment, to lowest level of treatment. The lower the level of treatment, the higher the level of exposure reductions measures are required.

Given that the MLA is large in size and relatively isolated, it would be feasible to implement a range of exposure reduction measures such as buffers, restriction of public access or spray drift control. If these exposure reduction measures are utilised this would warrant only aiming for secondary treatment quality.

Further recommendations on appropriate buffer distances are provided in **Section 10.2**.

8.2 ODOUR

Odour can be released by the sewage treatment plant and the irrigation field. Odour is spread in a similar manner to that of aerosols and can be dealt with in a similar manner.

Odour can be reduced by aiming for a higher level of treatment, otherwise set back distances tend to be highly effective in addition to aerosol reduction measures (i.e. using aerosol limiting spray methods). Timing also plays a part in minimising odour drift, such as avoiding irrigation when prevalent wind direction is towards nearby accommodation facilities. Irrigation can also be best timed during the day when staff are at work. Avoid irrigating in periods such as cold still winter nights when temperature inversions commonly occur and “trap” odours towards the ground.

8.3 TOXINS

Aside from nutrients and pathogens, wastewater can contain other toxins. Domestic sources of wastewater can contain heavy metals, pesticides and pharmaceuticals. These tend to only pose a direct risk to humans if the treated wastewater is intended for re-use to supplement a drinking water supply. In such cases the wastewater must be treated to an extremely high level to address these risks.

In this case the only risk posed by toxins is via aerosol exposure which could result in dermal contact or inhalation. This would generally need to occur via prolonged period to result in any noticeable effects. The most effective way to minimise health risks from toxins is to reduce the production of aerosols during irrigation, implement access restrictions to the irrigation area, and ensure buffer zones are implemented as per **Section 10.2**.Table 8-2: Examples of how pathogen log reduction targets can be achieved for Municipal Irrigation systems (Source – National Guidelines for Water Recycling)

Log reduction targets (Virus, Protozoa, Bacteria) [a]	Indicative treatment process	Log reductions achievable by treatment (V, P, B)	On-site preventative measures	Exposure reduction [b]	Water quality objectives [c]
Municipal use – open use, sports grounds, golf courses, dust suppression, etc *or* unrestricted access and application					
5.0 3.5 4.0	Advanced treatment required; for example: Secondary, coagulation, filtration and disinfection Secondary, membrane filtration, UV light	5.0 3.5 4.0	No specific measures		To be determined on case-by-case basis depending on technologies Could include turbidity criteria for filtration, disinfectant Ct or dose (UV) *E. coli* < 1 per 100ml
Municipal use, with restricted access and application					
5.0 3.5 4.0	Secondary treatment with disinfection	2.0 - 3.0 1.0 >6.0	Restrict public access during irrigation **and one** of the following: • No access after irrigation, until dry (1-4 hours) • Minimum 25-30m buffer to nearest point of public access • Spray drift control; for example, through low-throw sprinklers (180º inward throw), vegetation screening, or anemometer switching	2.0 1.0 1.0 1.0	• BOD < 20mg/L[d] • SS < 30mg/L[d] • Disinfectant residual (e.g. minimum chlorine residual) or UV dose[e] • *E. coli* < 100cfu/100mL
Municipal use, with enhanced restrictions on access and application					
5.0 3.5 4.0	• Secondary treatment with > 25 days lagoon detention or primary treatment with > 50 days lagoon detention • Secondary treatment	1.0 – 3.0 1.0 – 3.0 3.0 – 4.0 0.5 – 2.0 0.5 – 1.0 1.0 – 3.0	Restrict public access during irrigation **and combinations** of: • No access after irrigation, until dry (1-4 hours) • Minimum 25-30m buffer to nearest point of public access • Spray drift control, e.g. through low throw sprinklers (180º inward throw), vegetation screening or anemometer switching	2.0 1.0 1.0 1.0	• BOD < 20mg/L[d] • SS < 30mg/L[d] • *E. coli* < 1000 cfu/100mL (disinfection may be required to achieve this concentration)

B = enteric bacteria; BOD = biochemical oxygen demand; cfu = colony forming unit; Ct = disinfectant concentration x time; P = enteric protozoa; SS = suspended solid; V = enteric virus; UV = ultraviolet.

a Log reduction targets are minimum reductions required from raw sewage based on 95th percentiles from Table 3.7 of guideline.

b Exposure reductions are those achievable by on-site measures as listed in Table 3.3 of guideline.

c Water quality objectives represent medians for numbers of *E. coli* and means for other parameters.

d BOD and SS are an indication of secondary treatment effectiveness.

e Aim is to demonstrate reliability of disinfection and ability to consistently achieve microbial quality.

f Log reductions for public in the vicinity of commercial food crop irrigation areas should comply with total log reductions required for municipal use.

9.0 TREATMENT PLANT RECOMMENDATIONS

9.1 STANDARD OF WASTEWATER TREATMENT

The MEDLI 2.0 model confirms that a standard secondary treated effluent as per **Table 4-1** and **Table 4-2** can be irrigated within the investigation area without overloading the modelled Rhodes Grass or soil with nutrients.

In terms of pathogen treatment capability, the classes of recycled water quality as per the Queensland Public Health Regulation 2018 are as per **Table 9-1**.

- By utilising, for example, enhanced access restrictions (as per the last row of **Table 8-2**) a Class C recycled water quality would be acceptable standard of wastewater treatment.
- If irrigation area restrictions need to be eased slightly (as per the middle row of **Table 8-2**) a Class B water quality may be required.
- If no restrictions are in place (as per the top row of **Table 8-2**), and staff/public can readily access the irrigation area then a Class A + quality may be required.

Table 9-1: Classes of Recycled Water

E.coli count	Class of Recycled Water
<1 cfu/100mL*	Class A+
<10 cfu/100mL	Class A
<100 cfu/100mL	Class B
<1000 cfu/100mL	Class C
<10,000 cfu/100mL	Class D

*to achieve A+ compliance other pathogens such as Clostridium perfringens, F-specific RNA coliphages, and somatic coliphages must also be tested for.

9.2 PACKAGE TREATMENT PLANT OPTIONS

Many remote mining camps rely on package STPs which can be delivered in shipping containers and assembled on site. These are scaled down STPs having a small footprint and are generally highly efficient and of low maintenance requirements. Most package STPs come with standard Class C treatment capability, and many come with upgrade options allowing them to readily achieve Class A treatment capability.

During detailed design the most applicable treatment plant type can be decided upon. At this stage, it is recommended that a low maintenance system with secondary treatment capability and ability to produce at least Class C effluent should be adopted pending irrigation area restrictions detailed in **Table 8-2**. If irrigation area restriction requirements for Class C effluent are not feasible, a low maintenance system with secondary treatment capacity should be selected with effluent quality capability of Class B or Class A in accordance with the management measures outlined in **Table 8-2**.

10.0 SET OUT AND MANAGEMENT OF IRRIGATION AREA

10.1 SPRAY IRRIGATION SPECIFICATIONS

The irrigation system will adopt recommendations from AS/NZS 1547:2012 as determined to be appropriate. Key considerations are outlined in the following sections.

10.1.1 Designated Disposal Area

The designated irrigation area:

Is not to be used for purposes that compromise the effectiveness of the system or access for future maintenance purposes;

Is to be used only for effluent application;

Will have boundaries clearly delineated and not accessible to livestock to minimise damage;

Will be constructed to capture run-off and seepage of effluent beyond the designated area; and

Will have appropriate buffer areas maintained.

10.1.2 Irrigation System

The spray-irrigation system will be designed to:

Distribute effluent evenly in the designated area;

Control the droplet size, throw and plume height so that the risk of aerosol dispersion and the likelihood of wind draft distributing any effluent beyond the designated area is negligible;

Have warnings complying with AS 1319 or AS/NZS 1319, at the boundaries of the designated area, clearly visible to property users, with wording such as “Recycled Water – Avoid Contact – DO NOT DRINK”; and

Have a buffer area to ensure that any potential spray drift is adsorbed within appropriate setback distances.

10.2 BUFFER DISTANCES

The QLD Government Technical Guideline for Disposal of Effluent via Irrigation provide the following distances for reducing the risk associated with land disposal schemes using effluent irrigation:

Natural waterways: >100 m

Residential facility or public amenities: >50 m

Domestic water bore: > 250 m

Drinking water catchment and aquatic ecosystems with high ecological value: > 250 m

Town water supply bore: > 1000m

Groundwater bore used for potable water supply: >250 m; and

Groundwater table at a depth: >3 m.

It is recognised that the public buffer of 50 m is greater than that suggested in **Table 8-2**. As a conservative measure, it is recommended to implement a 50 m buffer.

10.3 MAINTAINING PASTURE

The MEDLI 2.0 model assumes that when the grass is mowed, that the grass clippings are removed from the area so that the nutrients within the grass clippings are removed with them. There are a couple of ways to achieve this, by either using a mower with a catcher, or by removing the grass clippings after mowing has been completed (e.g. mower grass catcher, leaf blower or raking).

The MEDLI 2.0 model indicates that mowing would only be required approximately 3 times per year to maintain sufficient growth and subsequent nutrient uptake. The grass can be mowed more frequently to maintain aesthetics if required.

10.4 MONITORING PROGRAM

Once detailed design progresses a risk assessment of the irrigation scheme will be undertaken to determine site-specific monitoring requirements. The monitoring program will be designed in accordance with the DES technical guideline *Disposal of Effluent using Irrigation* and can be adopted into the Irrigation Management Plan. The monitoring program may include periodic monitoring of soil, groundwater and any available surface water in close proximity to the irrigation area. Often such monitoring programs include 6 monthly or annual monitoring for nutrients, salts, sodicity and contaminants such as metals/metalloids and pesticides.

10.5 MANAGING SOIL SODICITY

As discussed in Section 5.2 the subsoil is likely to be sodic. Sodic soils tend to disperse readily when in contact with water. Dispersion can become an issue because as the fine soil particles “dissolve” they tend to become deposited within the soil pore spaces, thereby causing the soil to become clogged and less permeable.

The MEDLI model does not have the ability to account for changes to the soil profile resulting from dispersion therefore additional measures need to be taken to prevent it from occurring. The Department of Environment and Resource Management - *Salinity Management Handbook Second Edition 2011* provides a range of management measures which can be used to manage salinity and sodicity in soils.

It is possible to balance the soil Sodium Adsorption Ratio (SAR) by addition of calcium (typically gypsum) into the soil profile. Application of gypsum works on the principle that the calcium added to the soil will counterbalance the sodium. The addition of gypsum can result in better surface soil aggregation and consequently reduced waterlogging and crusting and can improve drainage.

Gypsum could be added to the upper soil profile with the aim of leaching the calcium into the underlying clay profile. Gypsum has a relatively low solubility, and it is estimated that on average only 1 tonne/ha/year of pure gypsum can be dissolved (Ayers & Westcot 1976). Due to the impurities in gypsum, unevenness of distribution and loss from surface runoff, the general recommendation is the application of 2-6 t/ha.

11.0 CONCLUSIONS AND RECOMMENDATIONS

The model results presented are based on conservatively estimated wastewater volumes and treated water quality. These conclusions are therefore conservative and can likely be refined further during detailed design.

11.1 DISPOSAL AREA SIZE AND STORAGE REQUIREMENTS

During operation a conservative volume of **29.2m^3** per day of secondary treated effluent with a quality as per **Table 4-1** and **Table 4-2** is expected to be generated. This effluent can be irrigated over **1,8 ha** at no more than **2 mm/day** without nutrient leaching, waterlogging, runoff or overflow issues arising. The Queensland Government Technical Guideline for Disposal of Effluent via Irrigation recommends **88m^3** of wet weather storage (3 days) should be provided.

11.2 LOCATION OF DISPOSAL AREA

The irrigation disposal area can be located anywhere within the investigation area, using whichever shape is most practical. The investigation area is sufficiently large to accommodate the modelled irrigation area size.

11.3 MANAGING PATHOGEN EXPOSURE RISK

It will likely be reasonable and practical to restrict public/staff access to the irrigation area, and restrict the irrigation application method to that shown in the last row in Table 8-2. As a result, the risk of pathogen exposure to the public/staff is low enough justify a secondary treated Class C recycled water quality requirement.

11.4 MANAGING SOIL SODICITY

The soil in the proposed effluent disposal area is sodic and therefore prone to dispersion. Dispersion can lead to further reduction in soil permeability. Management advice to reduce sodicity/dispersion is presented in Section 10.5.

11.5 STANDARD OF ASSESSMENT AND LIMITATIONS

This Land-Based Effluent Disposal Assessment Report has been undertaken in accordance with the current industry standard for wastewater management as set out in AS/NZS 1547:2012 *On-site Domestic Wastewater Management.*

12.0 REFERENCES

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APPENDICES

Appendix A EXTREME IMPERMEABLE MEDLI MODEL OUTPUT REPORT

MEDLI REPORT - FULL RUN

Enterprise: **Vecco Mine Extreme Impermeable**

Description:
Clay Based Model

Client: **Vecco**

MEDLI User: CARDNO\mark.farrey

Scenario Details:
Extreme Impermeable - Clay Soil
- Max capacity 146 employees
- 88 m3 tank
- 2mm/day max irrigation
- Rhodes Grass
- 1.8ha

DESCRIPTION

Climate Data: Vecco Mine, -19.95°, 141.9°

Run Period: 01/01/1970 to 31/12/2022 53 years, 0 days

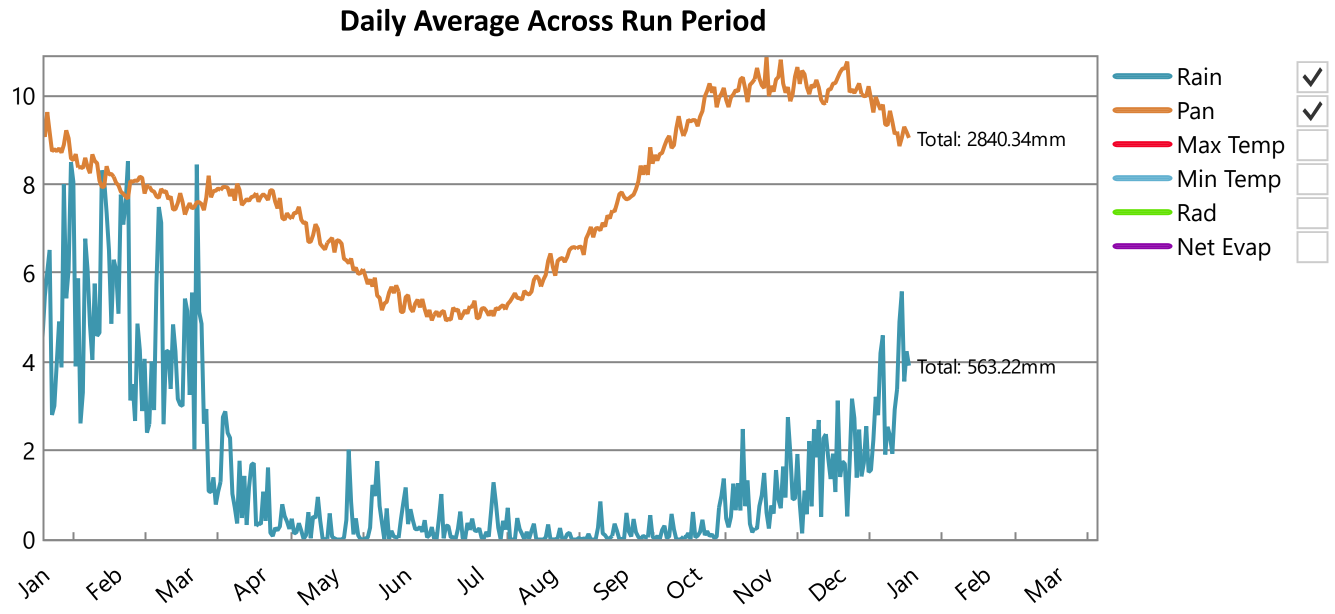
Climate Statistics:

	5th Percentile	50th Percentile	95th Percentile
Rainfall (mm/year)	293	533	1024
Pan Evaporation (mm/year)	2437	2837	3207

Climate Data:

■ Chart ☐ Table

☐ Monthly ■ Daily



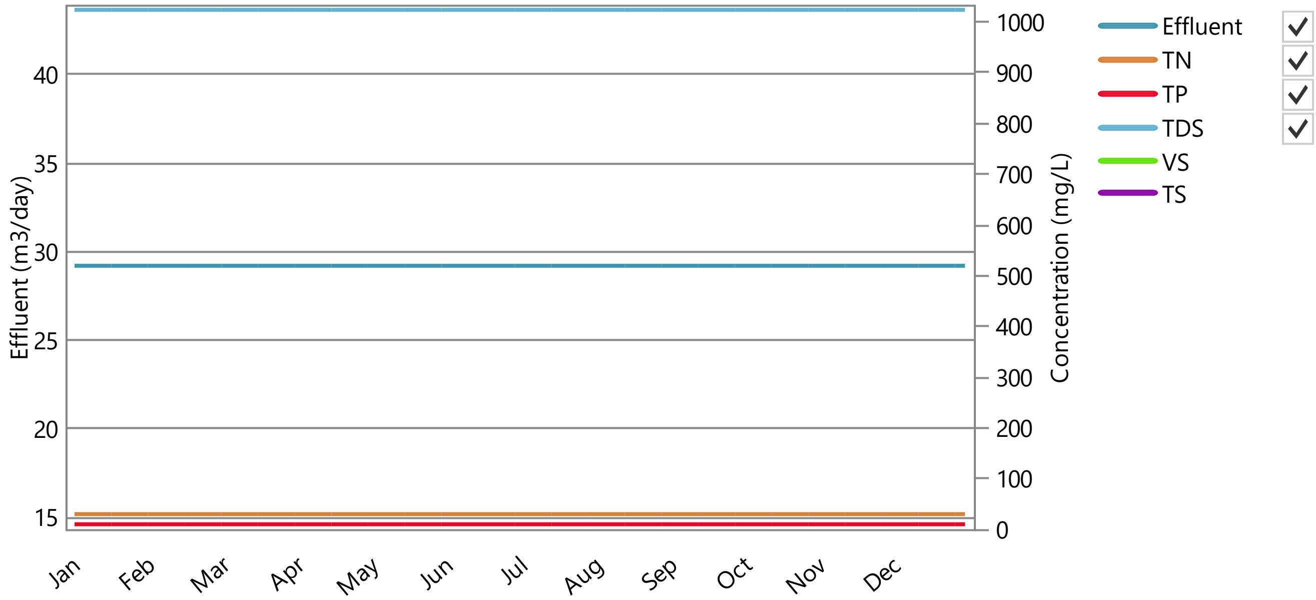
DESCRIPTION

Effluent type: Vecco STP

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:

Chart Table



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: **10665.16 m3/year** or 29.20 m3/day (Min-Max: 29.20 - 29.20)

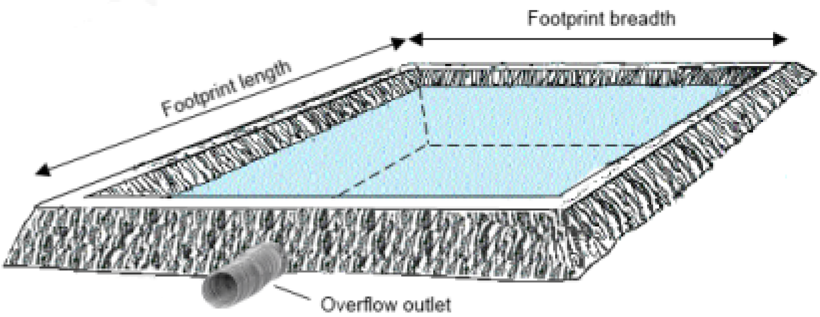
Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

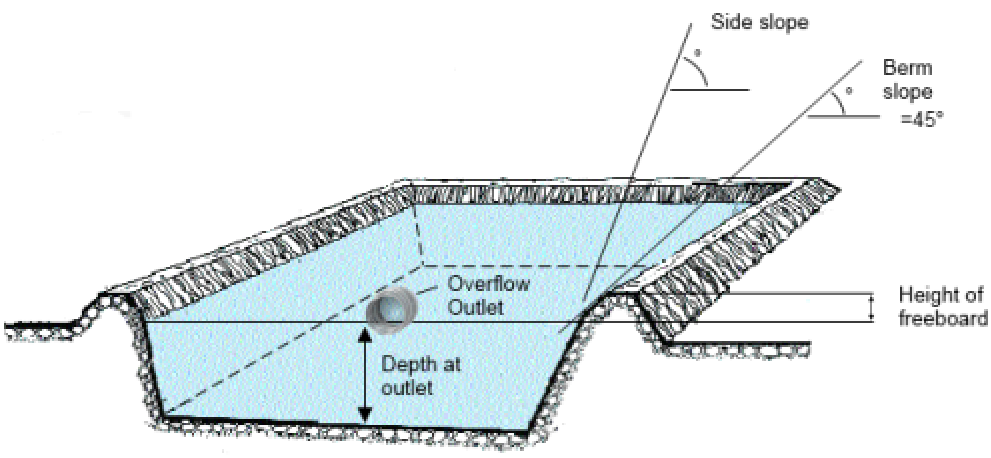
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	319.95 (319.74 - 320.62)
Total Phosphorus	10.00 (10.00 - 10.00)	106.65 (106.58 - 106.87)
Total Dissolved Salts	1024.00 (1024.00 - 1024.00)	10921.13 (10913.79 - 10943.69)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (m3)	88.00
Minimum allowable pond volume (m3)	0.00
Pond depth at overflow outlet (m)	3.00
Maximum water surface area (m2)	29.33
Pond footprint length (m)	5.42
Pond footprint width (m)	5.42
Pond catchment area (m2)	29.33
Average active volume (m3)	0.00





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.00
Maximum pump rate limit (ML/day)	999999999.00

Shandying water:

Annual allocation of fresh water available for shandying (m3/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

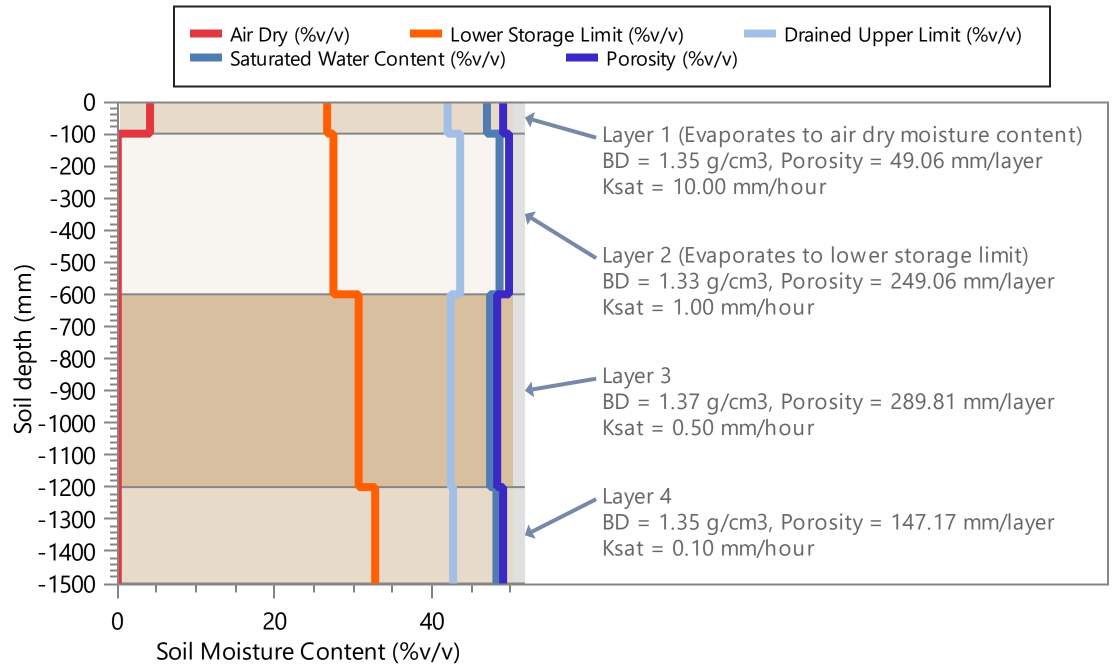
DESCRIPTION

Land: New Paddock

Area (ha): 1.80

Soil Type: Grey Clay, 1500.00 mm defined profile depth

Profile Porosity (mm)	735.09
Profile saturation water content (mm)	719.00
Profile drained upper limit (or field capacity) (mm)	642.50
Profile lower storage limit (or permanent wilting point) (mm)	446.80
Profile available water capacity (mm)	195.70
Profile limiting saturated hydraulic conductivity (mm/hour)	0.10
Surface saturated hydraulic conductivity (mm/hour)	10.00
Runoff curve number II (coefficient)	75.00
Soil evaporation U (mm)	6.00
Soil evaporation Cona (mm/sqrt day)	3.50



Plant Data: Continuous Rhodes Grass Pasture

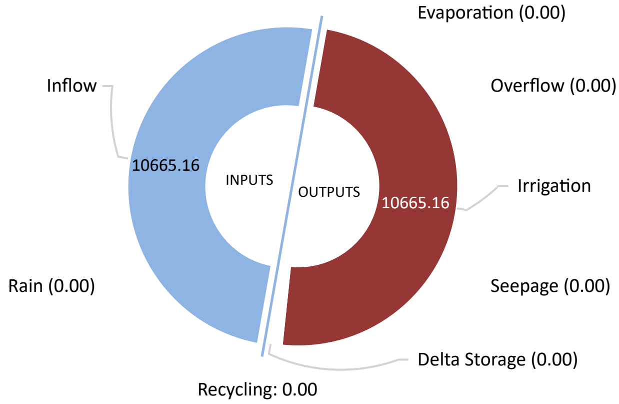
Average monthly cover (fraction) (minimum - maximum)	0.71 (0.68 - 0.73)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.9 x Pan coefficient 1)	0.90
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	1200.00
Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03

PERFORMANCE

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **88 m3**

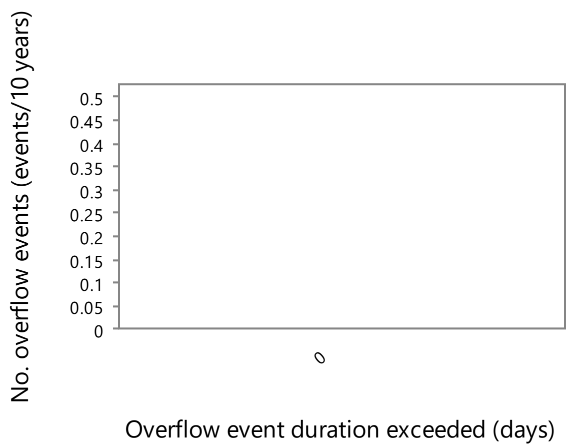
Pond System Water Balance (m3/year)

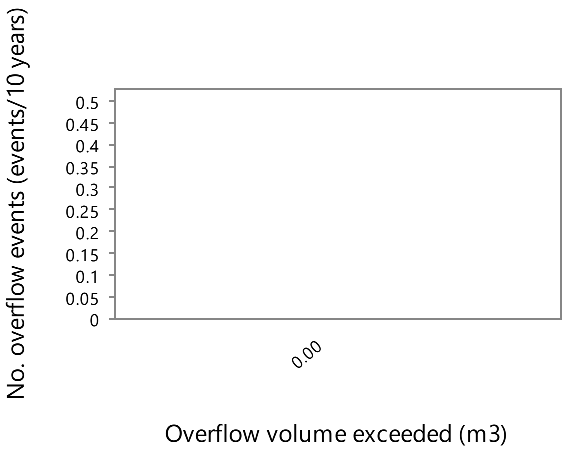


Name	Value
Rain	0.00
Inflow	10665.16
Recycling	0.00
Evaporation	0.00
Overflow	0.00
Irrigation	10665.16
Seepage	0.00
Delta Storage	0.00

Overflow Diagnostics

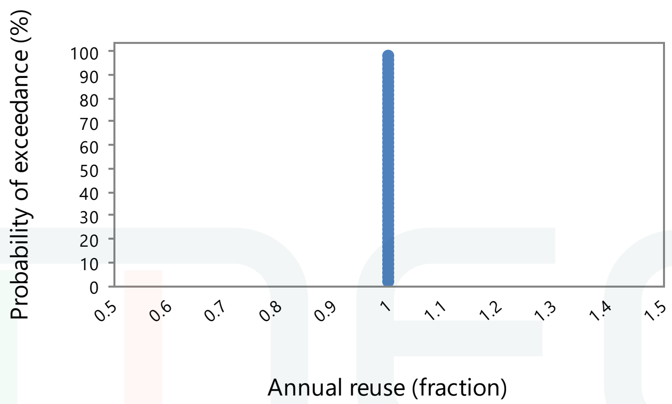
Volume of overflow (m3/year)	0.00
No. days pond overflows (days/year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% reuse (fraction)	1.00





Export plot

Export plot



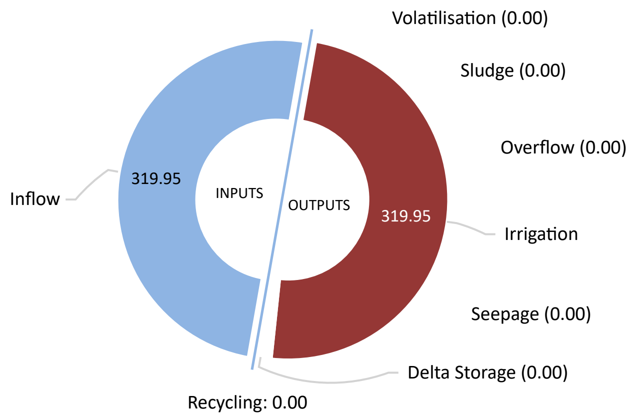
Export plot

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

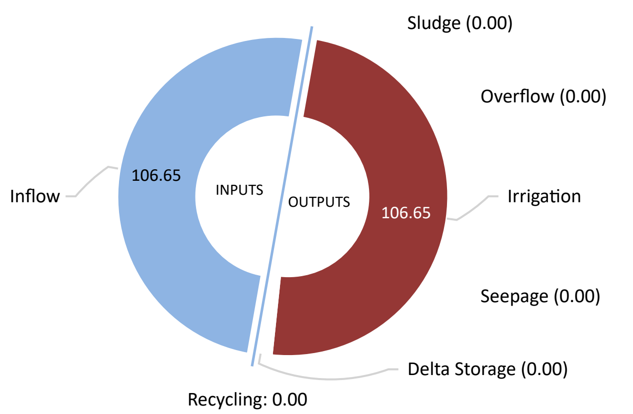
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



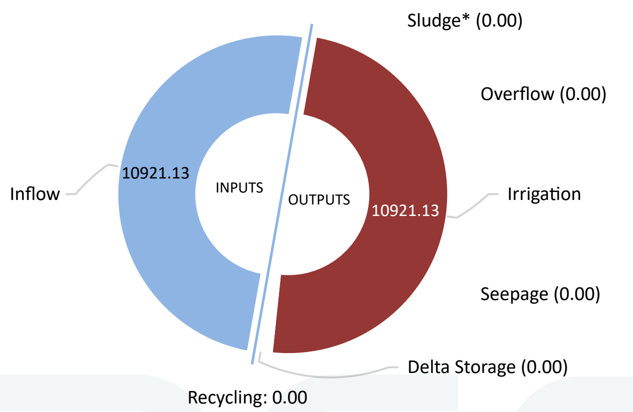
Name	Value
Inflow	319.95
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	0.00
Irrigation	319.95
Seepage	0.00
Delta Storage	0.00

Phosphorus Balance (kg/year)



Name	Value
Inflow	106.65
Recycling	0.00
Sludge	0.00
Overflow	0.00
Irrigation	106.65
Seepage	0.00
Delta Storage	0.00

Salt Balance (kg/year)



Name	Value
Inflow	10921.13
Recycling	0.00
Sludge*	0.00
Overflow	0.00
Irrigation	10921.13
Seepage	0.00
Delta Storage	0.00

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	30.00
Average phosphorus concentration of pond liquid (mg/L)	10.00
Average salinity of pond liquid (dS/m)	1.60

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	30.00
Final phosphorus concentration of pond liquid (mg/L)	10.00
Final salinity of pond liquid (dS/m)	1.60

PERFORMANCE

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (m3/year)	10665.16
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (m3/year)	10665.16
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	30.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	30.00
Average phosphorus concentration of irrigation water (mg/L)	10.00
Average salinity of irrigation water (dS/m)	1.60

Irrigation Diagnostics:

Proportion of Days irrigation occurs (fraction)	1.00

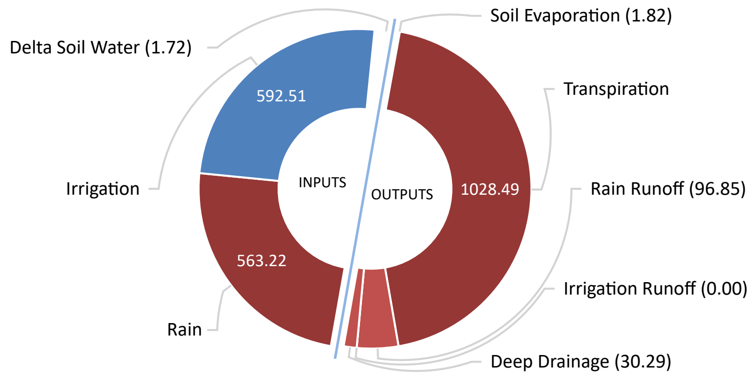
PERFORMANCE

Land Performance - Soil Water

Paddock: New Paddock, 1.8 ha
Soil Type: Grey Clay, 166.00 mm PAWC at maximum root depth

Land Water Balance (mm/year):

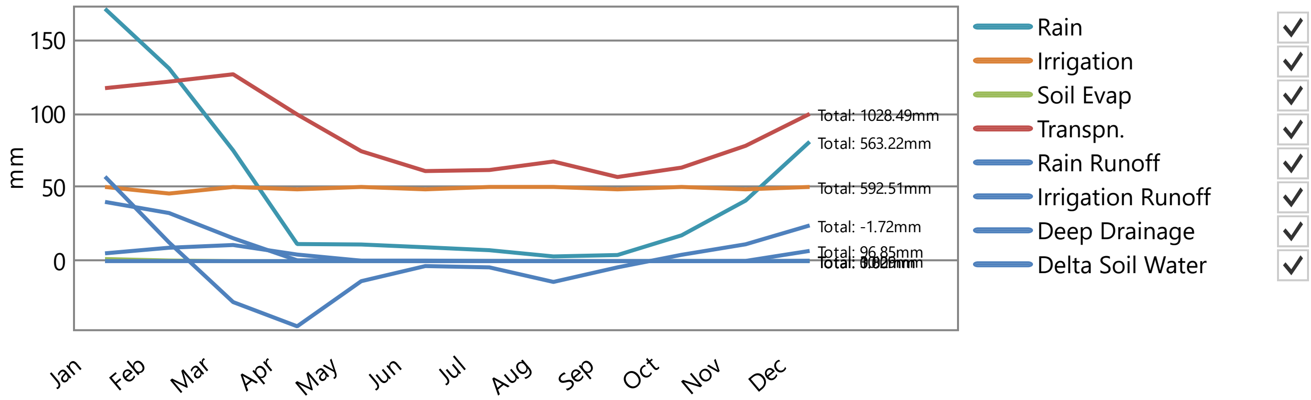
■ mm/year ☐ % Total inputs



Name	Value
Rain	563.22
Irrigation	592.51
Soil Evaporation	1.82
Transpiration	1028.49
Rain Runoff	96.85
Irrigation Runoff	0.00
Deep Drainage	30.29
Delta Soil Water	-1.72

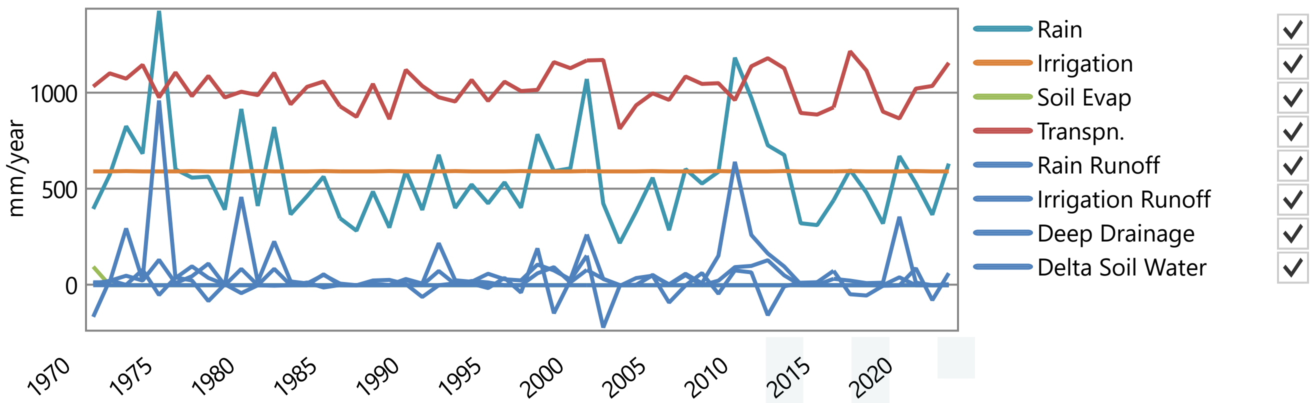
Average Monthly Totals (mm):

■ Chart ☐ Table



Average Annual Totals (mm/year):

■ Chart ☐ Table



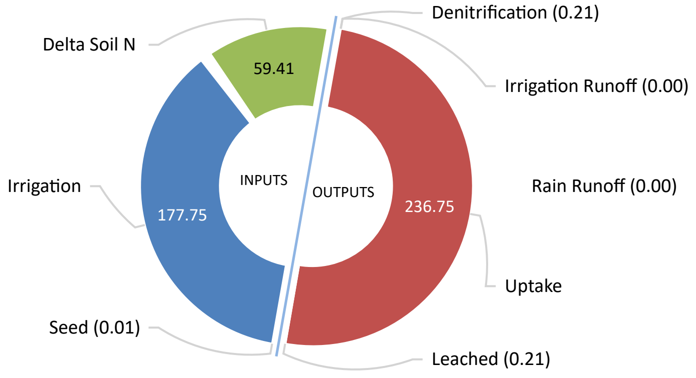
PERFORMANCE

Land Performance - Soil Nutrient

Paddock: New Paddock, 1.8 ha **Soil Type: Grey Clay**

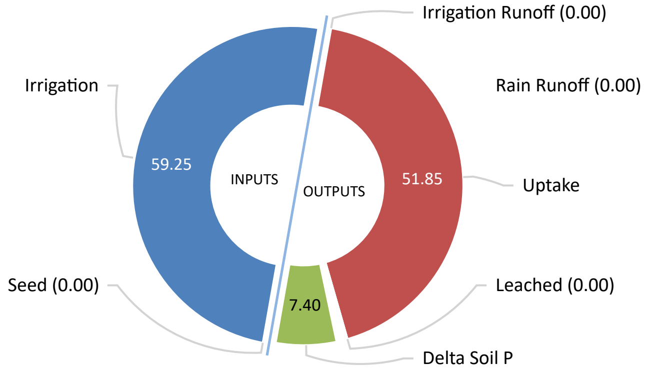
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.10

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.01
Irrigation	177.75
Denitrification	0.21
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	236.75
Leached	0.21
Delta Soil N	-59.41

Land Phosphorus Balance (kg/ha/year)



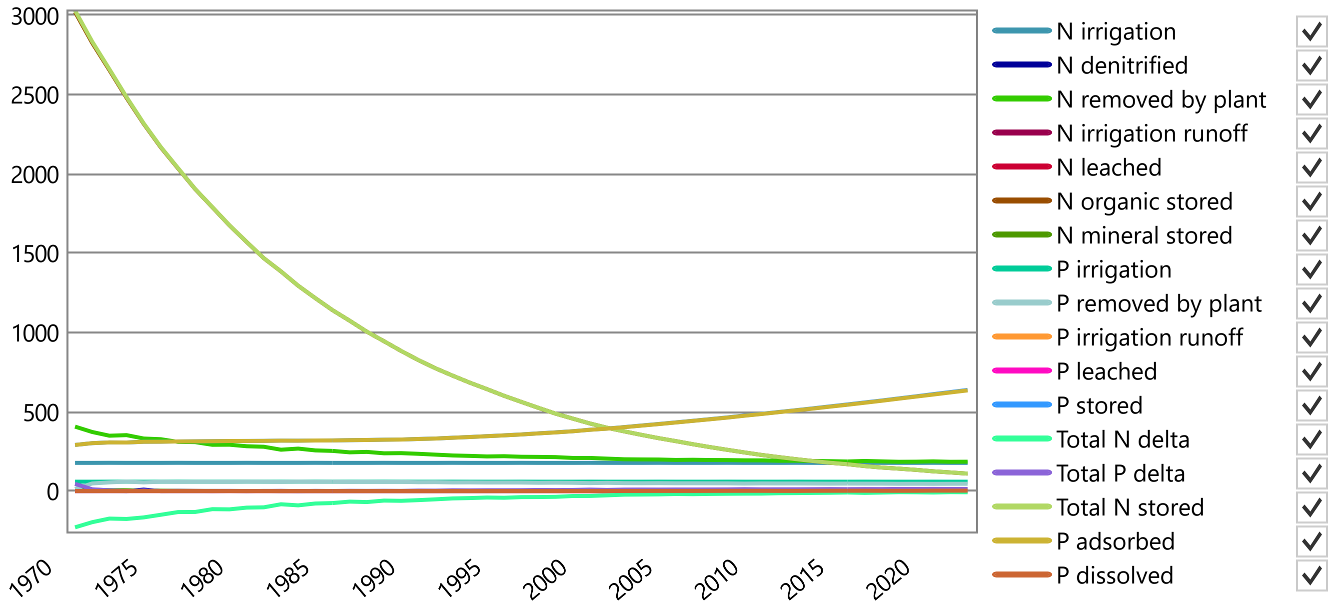
Name	Value
Seed	1.70E-03
Irrigation	59.25
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	51.85
Leached	3.02E-03
Delta Soil P	7.40

PERFORMANCE

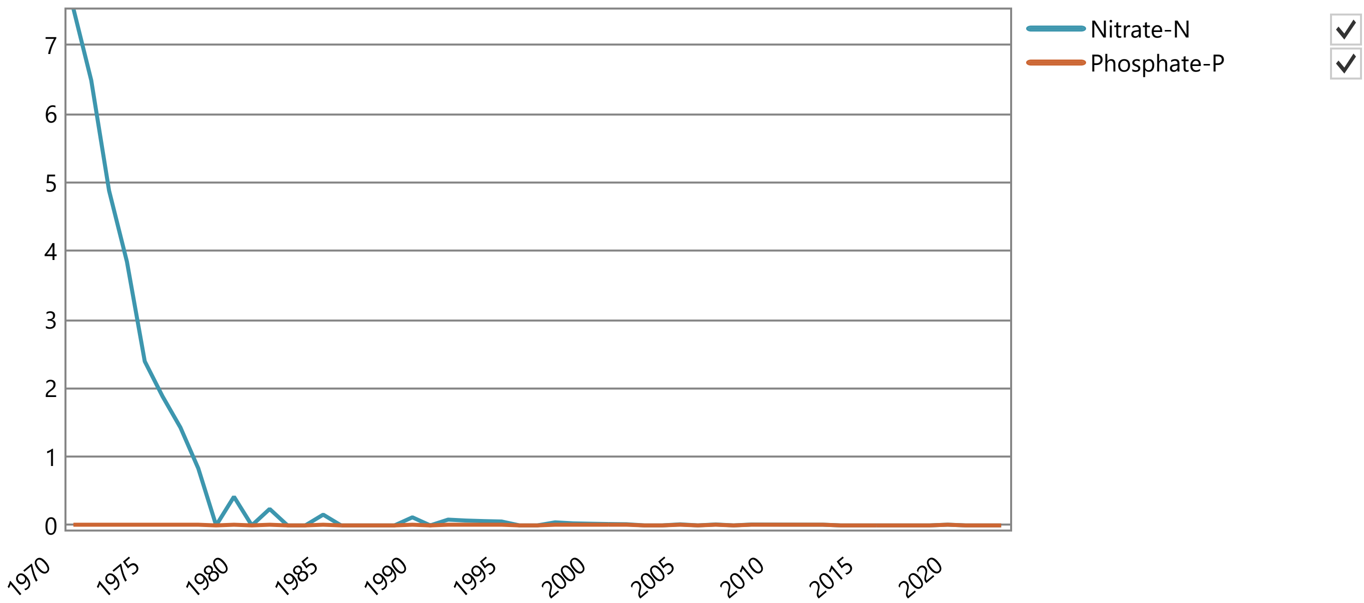
Land Performance - Soil Nutrient

Paddock: New Paddock, 1.8 ha **Soil Type**: Grey Clay

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



PERFORMANCE

Plant Performance and Nutrients

Paddock: New Paddock, 1.8 ha **Soil Type**: Grey Clay

Plant: Continuous Rhodes Grass Pasture

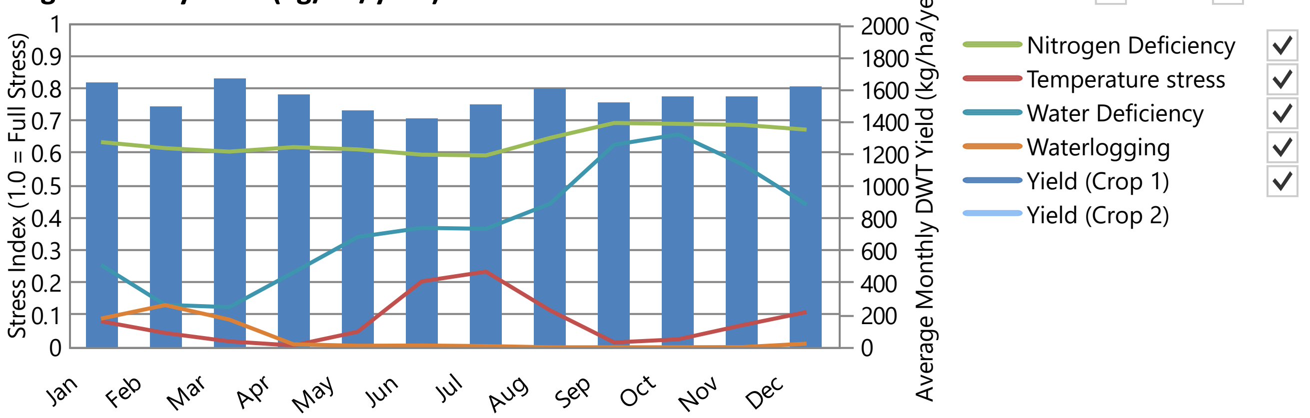
Average annual shoot dry matter yield (kg/ha/year)	18684.13 (15216.63 - 26785.02)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.71 (0.68 - 0.73)
Average monthly root depth (mm) (minimum - maximum)	1198.78 (1187.25 - 1200.00)

Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	236.75 (184.62 - 406.36)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	51.85 (13.88 - 59.68)
Average annual shoot nitrogen concentration (fraction dwt)	0.01 (0.01 - 0.02)
Average annual shoot phosphorus concentration (fraction dwt)	0.003 (0.001 - 0.003)

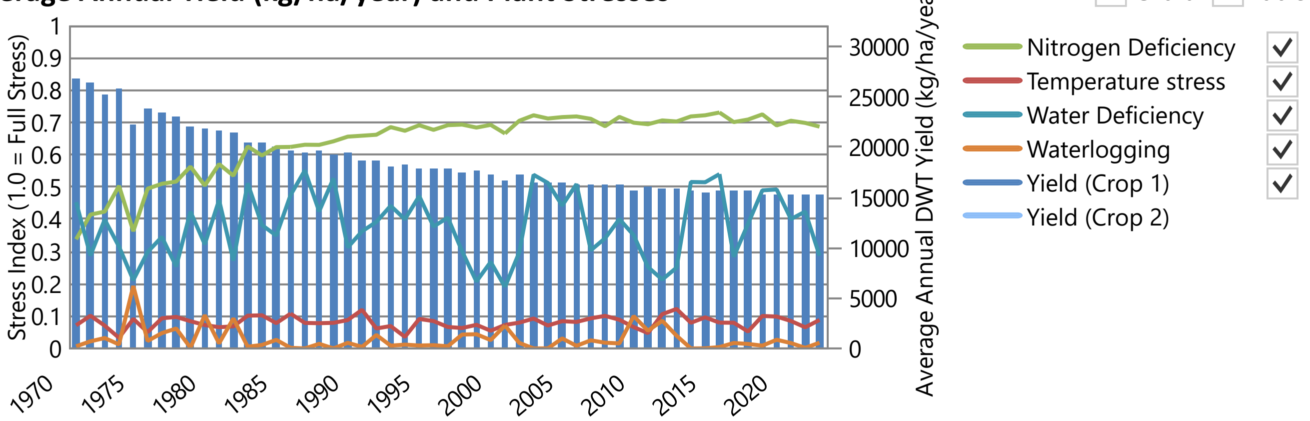
Average Monthly Yield (kg/ha/year) and Plant Stresses

Chart Table



Average Annual Yield (kg/ha/year) and Plant Stresses

Chart Table



No. of harvests/year: 3.25 (normal)
No. days without crop/year (days/year): 0.00

PERFORMANCE

Land Performance

Paddock: New Paddock, 1.8 ha **Soil Type**: Grey Clay

Plant: Continuous Rhodes Grass Pasture

Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03
No. years assumed for leaching to reach steady-state (years)	10.00

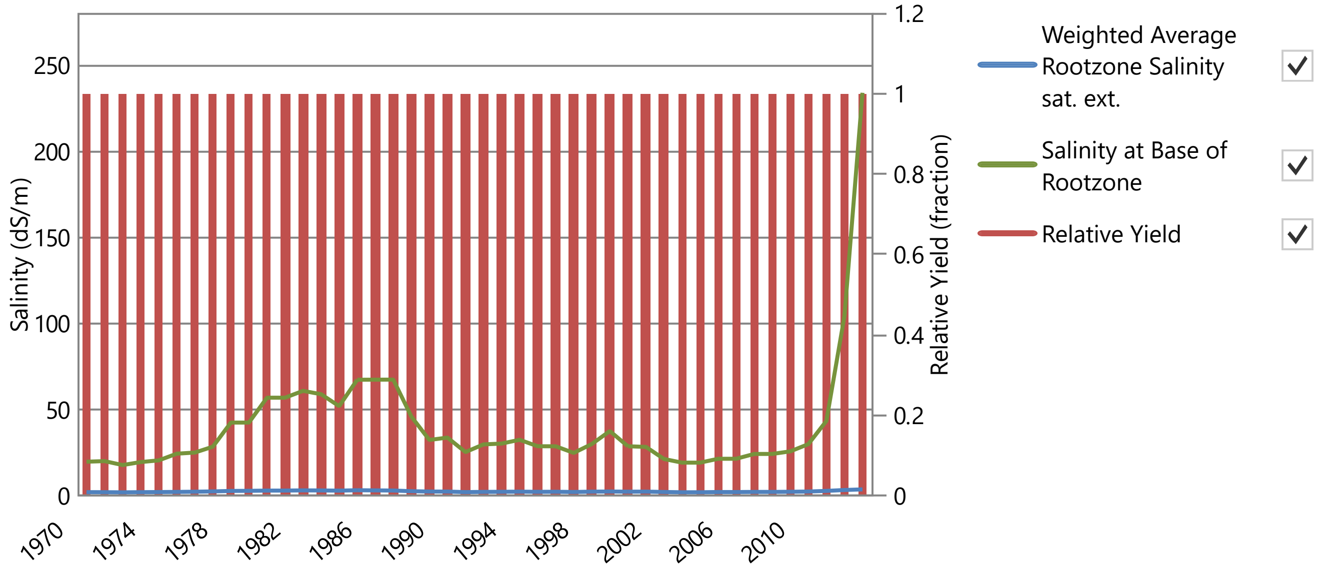
Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.91
Salt added by rainfall (kg/ha/year)	89.54
Average annual effluent salt added & leached at steady state (kg/ha/year)	6156.83
Average leaching fraction based on 10 year running averages (fraction)	0.18
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	2.34
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	40.18
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield:

■ Chart ☐ Table

All values based on 10 year running averages



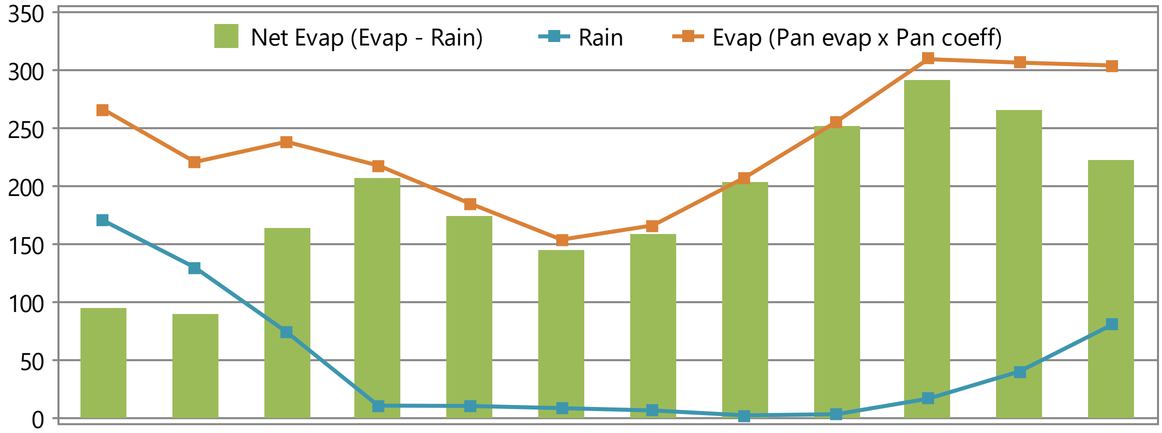
DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Impermeable

Averaged Historical Climate Data Used in Simulation (mm)

Location: Vecco Mine, -19.95°, 141.9°

Run Period: 01/01/1970 to 31/12/2022 53 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	171.1	130.6	75.1	11.6	11.3	9.4	7.4	3.2	4.1	17.5	41.0	81.0	563.2
Evap	266.9	221.6	239.0	218.6	185.9	154.6	167.0	208.1	256.3	310.2	307.2	304.8	2840.3
Net Evap	95.8	91.0	163.9	207.0	174.6	145.3	159.6	205.0	252.1	292.8	266.2	223.9	2277.1
Net Evap/day	3.1	3.2	5.3	6.9	5.6	4.8	5.1	6.6	8.4	9.4	8.9	7.2	6.2

Sustainability Diagnostics: Vecco Mine Extreme Impermeable

Pond System: 1 closed storage tank

Vecco STP - 10665.16 m3/year or 29.20 m3/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum influent quality calculated for 365.25 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	319.95 (319.74 - 320.62)
Total Phosphorus	10.00 (10.00 - 10.00)	106.65 (106.58 - 106.87)
Total Dissolved Salts	1024.00 (1024.00 - 1024.00)	10921.13 (10913.79 - 10943.69)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

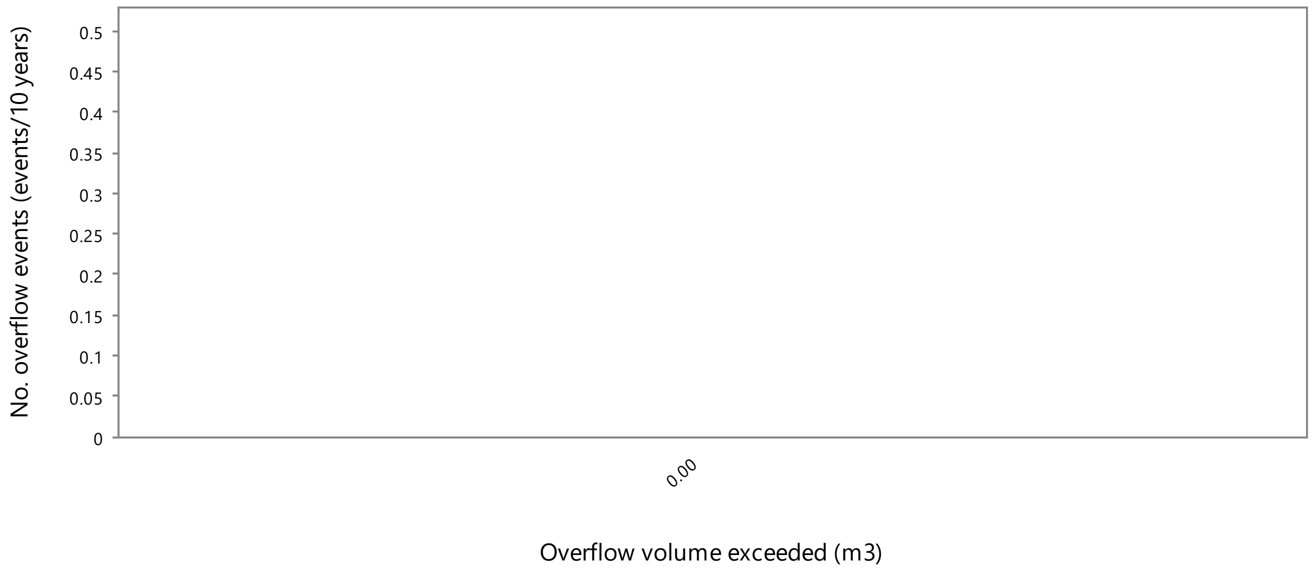
Last pond (Wet weather store): 88.00 m3

Theoretical hydraulic retention time (days)	3.01
Average volume of overflow (m3/year)	0.00
No. overflow events per year exceeding threshold* of 0.03 m3 (no./year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	1.60
Salinity of last pond on final day of simulation (dS/m)	1.60
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

■ Chart ☐ Table



Export plot

DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Impermeable

Irrigation Information

Irrigation: 1.8 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (m3)	10665.16	5925.09
Total nitrogen applied (kg)	319.95	177.75
Total phosphorus applied (kg)	106.65	59.25
Total salts applied (kg)	10921.13	6067.29

Shandying

Annual allocation of fresh water for shandying (m3/year)	0.00
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation occurs (fraction)	1.00

DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Impermeable

Paddock Land: New Paddock: 1.8 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Irrigation triggered every 1 days
Irrigate a fixed amount of 2.00 mm each day
Irrigation window from 1/1 to 31/12 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Grey Clay, 166.00 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	171.1	130.6	75.1	11.6	11.3	9.4	7.4	3.2	4.1	17.5	41.0	81.0	563.2
Irrigation	50.3	45.8	50.3	48.7	50.3	48.7	50.3	50.3	48.7	50.3	48.7	50.3	592.5
Soil Evap	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Transpn.	117.3	121.7	126.7	99.4	74.5	61.1	61.8	67.5	57.0	63.4	78.2	99.8	1028.5
Rain Runoff	40.1	32.6	15.5	0.6	0.3	0.3	0.2	0.0	0.0	0.1	0.1	6.9	96.9
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	5.3	9.1	10.9	4.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	30.3
Delta	57.3	12.6	-27.8	-44.2	-13.6	-3.4	-4.2	-14.1	-4.2	4.3	11.4	24.2	-1.7

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	177.75
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	236.75
Average annual soil nitrogen removed by denitrification (kg/ha/year)	0.21
Average annual soil nitrogen leached (kg/ha/year)	0.21
Average annual nitrate-N loading to groundwater (kg/ha/year)	0.21
Soil organic-N kg/ha (Initial - Final)	3208.00 - 109.92
	50.68 - 0.06
Average nitrate-N concentration of deep drainage (mg/L)	0.70
Max. annual nitrate-N concentration of deep drainage (mg/L)	7.53

Soil Phosphorus Balance

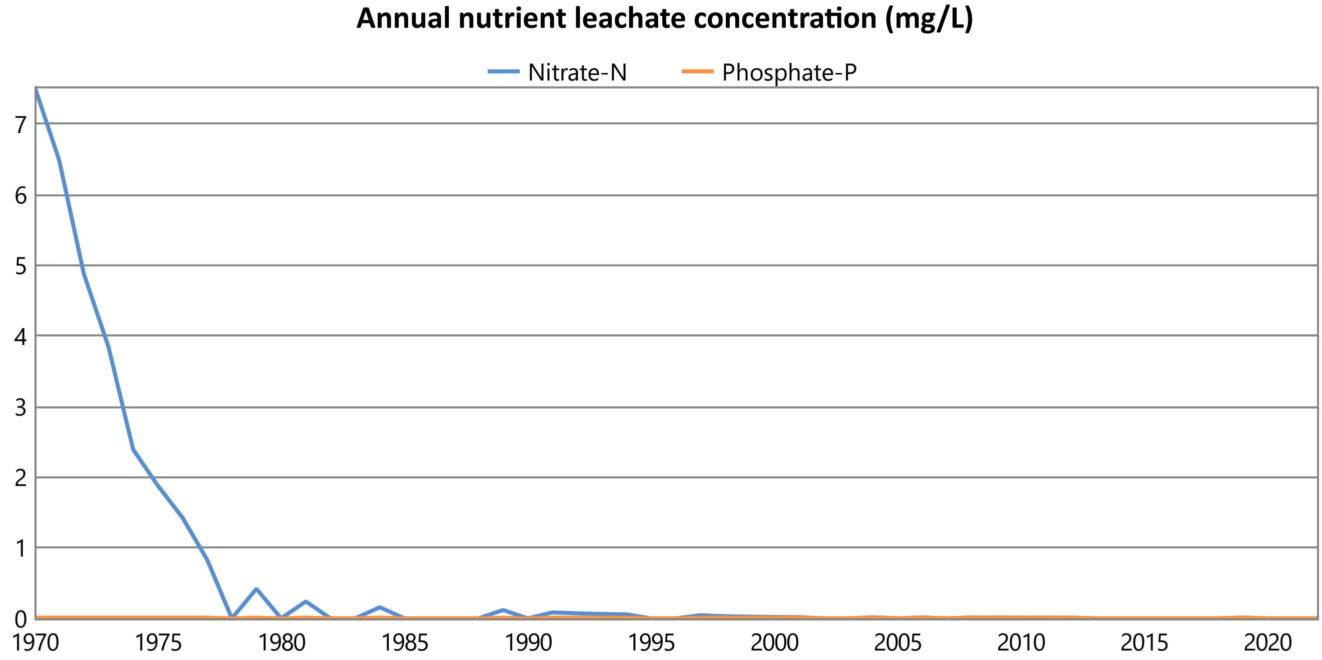
Average annual effluent phosphorus added (kg/ha/year)	59.25
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	51.85
Average annual soil phosphorus leached (kg/ha/year)	3.02E-03
Dissolved phosphorus (kg/ha) (Initial - Final)	0.06 - 2.74
Adsorbed phosphorus (kg/ha) (Initial - Final)	245.27 - 634.70
Average phosphate-P concentration in rootzone (mg/L)	0.15
Average phosphate-P concentration of deep drainage (mg/L)	0.01
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.01
Design soil profile storage life based on average infiltrated water phosphorus concn. of 5.60 mg/L (years)	44.94

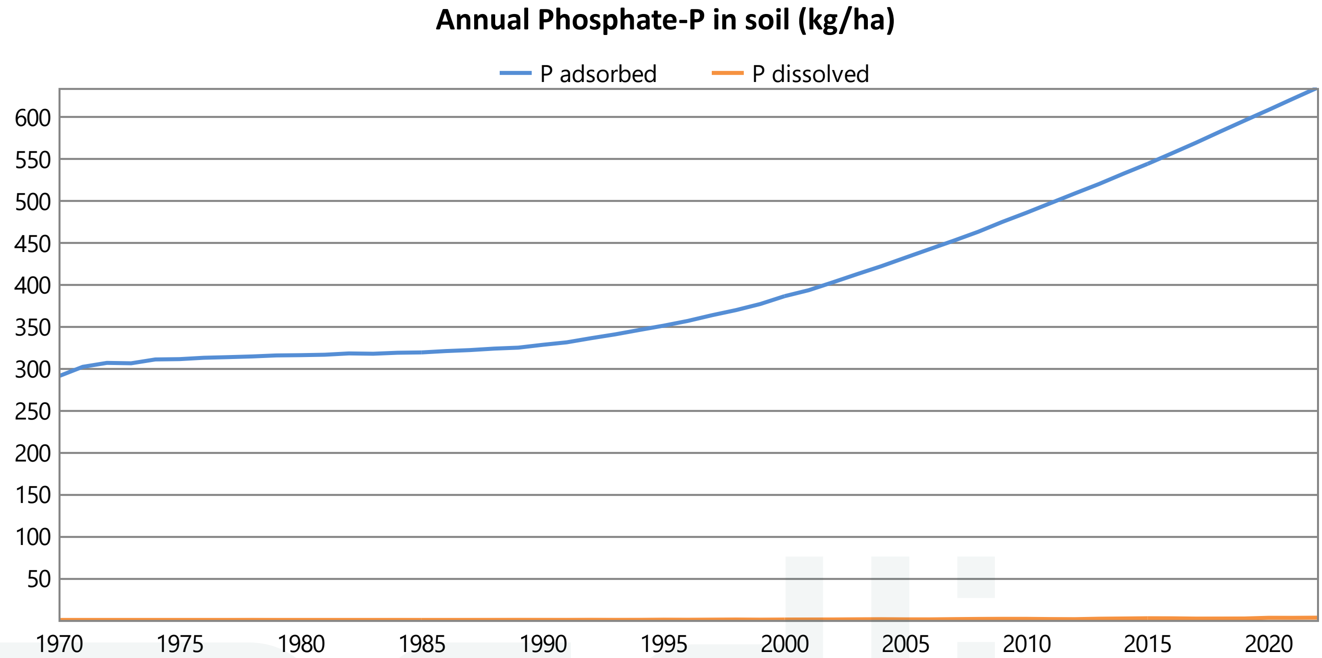
DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Impermeable

Paddock Land: New Paddock: 1.8 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation





DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Impermeable

Paddock Plant Performance: New Paddock: 1.8 ha

Average Plant Performance (Minimum - Maximum: Continuous Rhodes Grass Pasture

Average annual shoot dry matter yield (kg/ha/year)	18684.13 (15216.63 - 26785.02)
Average monthly plant (green) cover (fraction)	0.71 (0.68 - 0.73)
Average monthly crop factor (fraction)	0.64 (0.62 - 0.66)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	1198.78 (1187.25 - 1200.00)
Average number of normal harvests per year (no./year)	3.25 (2.00 - 5.00)
Average number of normal harvests for last five years only (no./year)	2.60
Average number of crop deaths per year (no./year)	0.00 (0.00 - 0.00)
Average number of crop deaths for last five years only (no./year)	0.00
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.64 (0.34 - 0.73)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.08 (0.00 - 0.21)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.23 (0.04 - 0.39)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.38 (0.12 - 0.66)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.03 (0.00 - 0.13)
No. days without crop/year (days)	0.00

Soil Salinity - Plant salinity tolerance: Tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.91
Salt added by rainfall (kg/ha/year)	89.54
Average annual effluent salt added & leached at steady state (kg/ha/year)	6156.83
Average leaching fraction based on 10 year running averages (fraction)	0.18
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	2.34
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	40.18
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

DIAGNOSTICS

Run Messages

Messages generated when the scenario was run:

Full run chosen

Appendix B EXTREME PERMEABLE MEDLI MODEL OUTPUT REPORT

MEDLI REPORT - FULL RUN

Enterprise: **Vecco Mine Extreme Permeable**

Description:
Sand Based Model

Client: **Vecco**

MEDLI User: CARDNO\mark.farrey

Scenario Details:
Extreme Permeable - Sand Soil
- Max capacity 146 employees
- 88 m3 tank
- 2mm/day max irrigation
- Rhodes Grass
- 1.5ha

DESCRIPTION

Climate Data: Vecco Mine, -19.95°, 141.9°

Run Period: 01/01/1970 to 31/12/2022 53 years, 0 days

Climate Statistics:

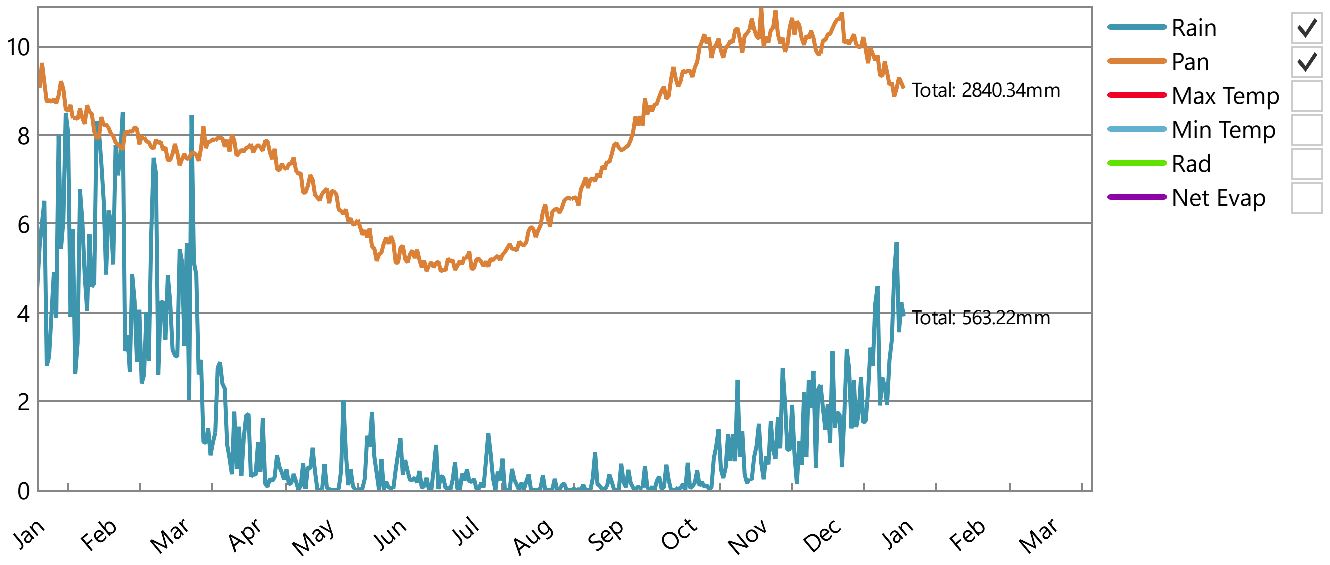
	5th Percentile	50th Percentile	95th Percentile
Rainfall (mm/year)	293	533	1024
Pan Evaporation (mm/year)	2437	2837	3207

Climate Data:

■ Chart ☐ Table

☐ Monthly ■ Daily

Daily Average Across Run Period



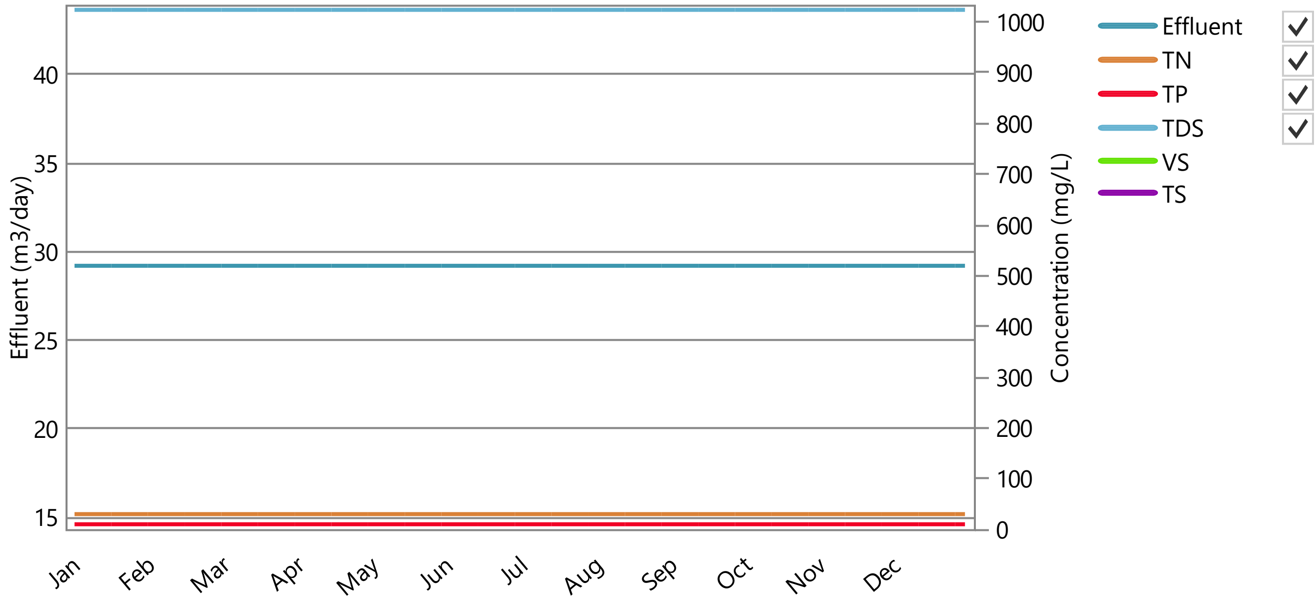
DESCRIPTION

Effluent type: Vecco STP

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:

Chart Table



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: 10665.16 m3/year or 29.20 m3/day (Min-Max: 29.20 - 29.20)

Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

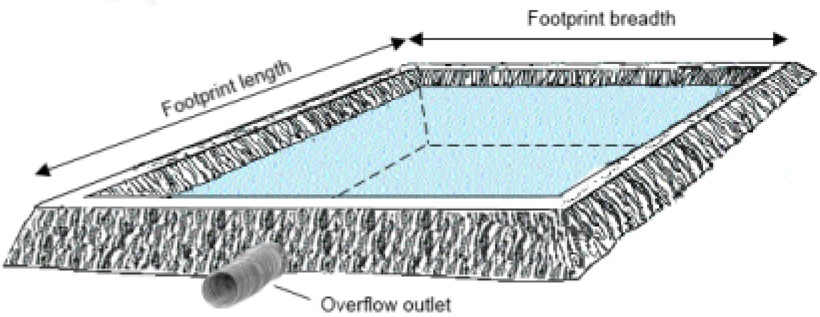
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	319.95 (319.74 - 320.62)
Total Phosphorus	10.00 (10.00 - 10.00)	106.65 (106.58 - 106.87)
Total Dissolved Salts	1024.00 (1024.00 - 1024.00)	10921.13 (10913.79 - 10943.69)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

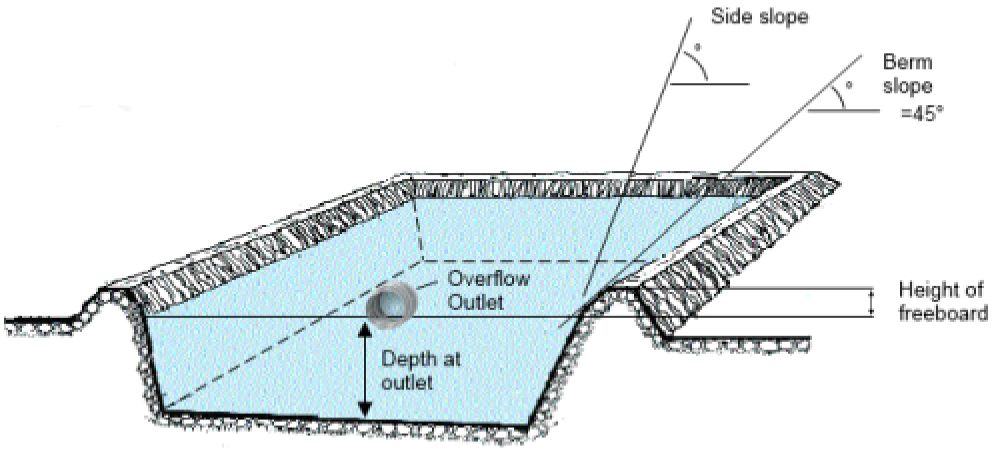
DESCRIPTION

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (m3)	88.00
Minimum allowable pond volume (m3)	0.00
Pond depth at overflow outlet (m)	3.00
Maximum water surface area (m2)	29.33
Pond footprint length (m)	5.42
Pond footprint width (m)	5.42
Pond catchment area (m2)	29.33
Average active volume (m3)	0.00





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.00
Maximum pump rate limit (ML/day)	999999999.00

Shandying water:

Annual allocation of fresh water available for shandying (m3/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

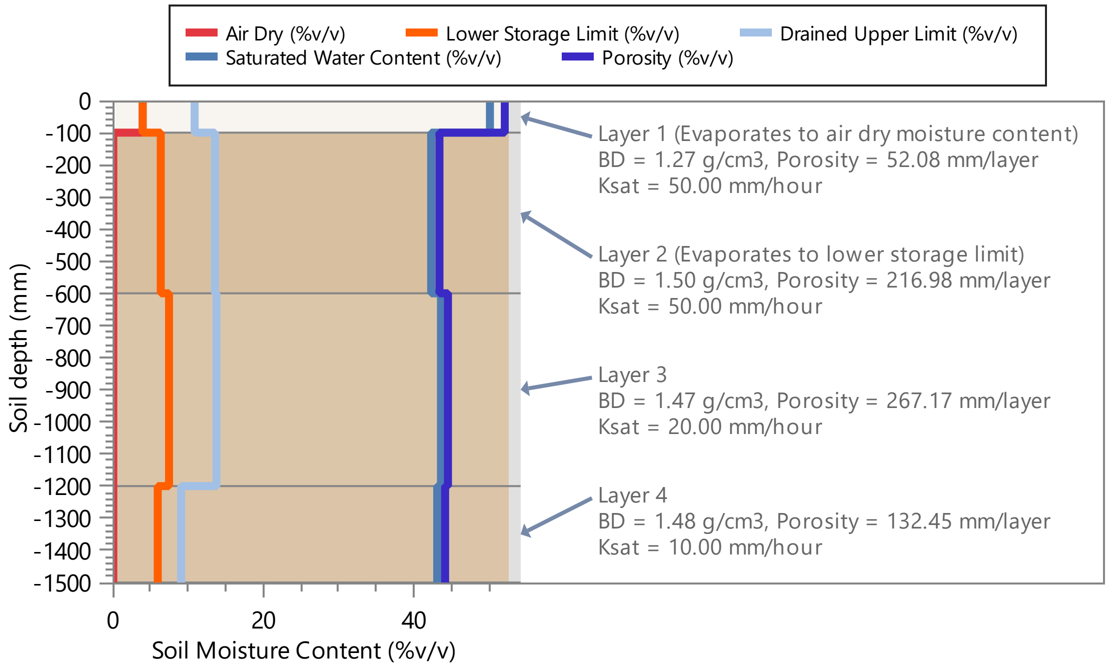
DESCRIPTION

Land: New Paddock

Area (ha): 1.50

Soil Type: Sand, 1500.00 mm defined profile depth

Profile Porosity (mm)	668.68
Profile saturation water content (mm)	652.50
Profile drained upper limit (or field capacity) (mm)	189.00
Profile lower storage limit (or permanent wilting point) (mm)	99.00
Profile available water capacity (mm)	90.00
Profile limiting saturated hydraulic conductivity (mm/hour)	10.00
Surface saturated hydraulic conductivity (mm/hour)	50.00
Runoff curve number II (coefficient)	70.00
Soil evaporation U (mm)	10.00
Soil evaporation Cona (mm/sqrt day)	4.50



Plant Data: Continuous Rhodes Grass Pasture

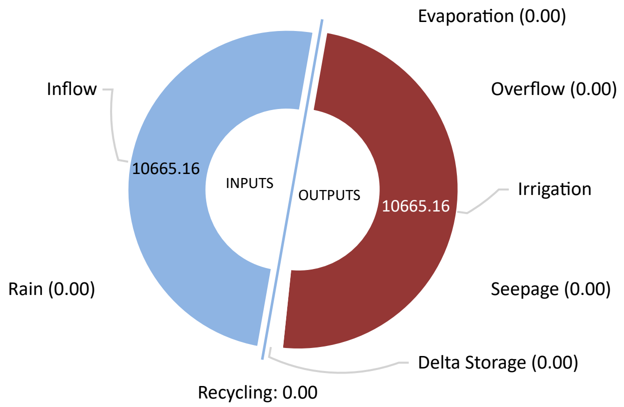
Average monthly cover (fraction) (minimum - maximum)	0.71 (0.68 - 0.73)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.9 x Pan coefficient 1)	0.90
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	1200.00
Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03

PERFORMANCE

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **88 m3**

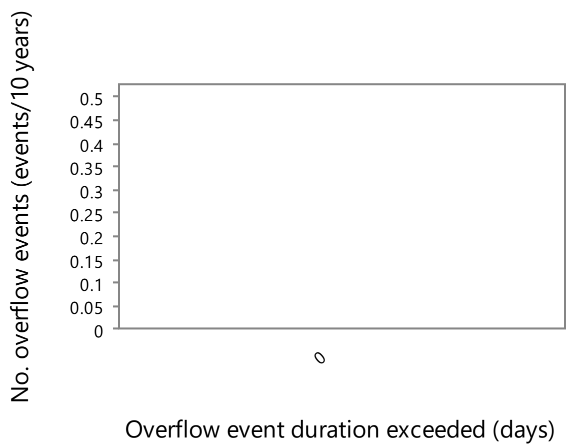
Pond System Water Balance (m3/year)

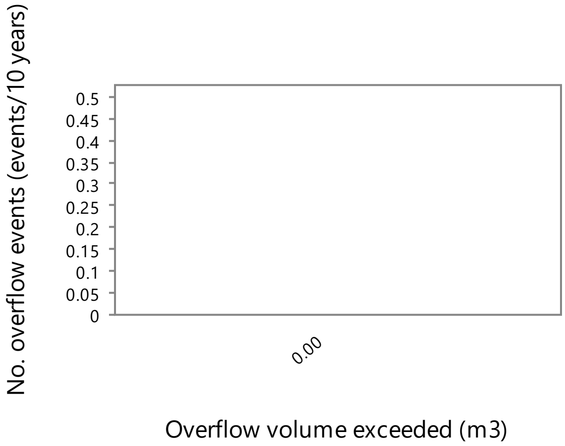


Name	Value
Rain	0.00
Inflow	10665.16
Recycling	0.00
Evaporation	0.00
Overflow	0.00
Irrigation	10665.16
Seepage	0.00
Delta Storage	0.00

Overflow Diagnostics

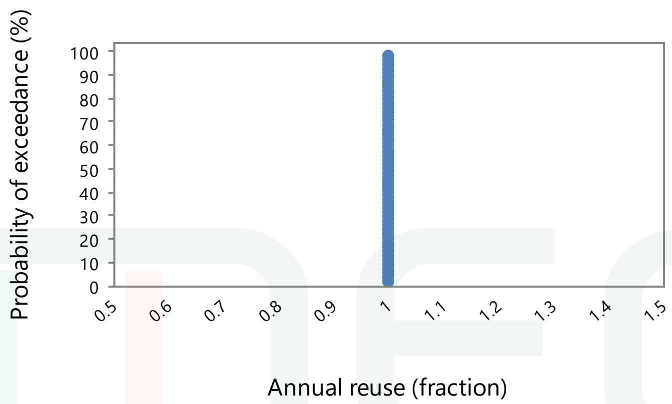
Volume of overflow (m3/year)	0.00
No. days pond overflows (days/year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% reuse (fraction)	1.00





Export plot

Export plot



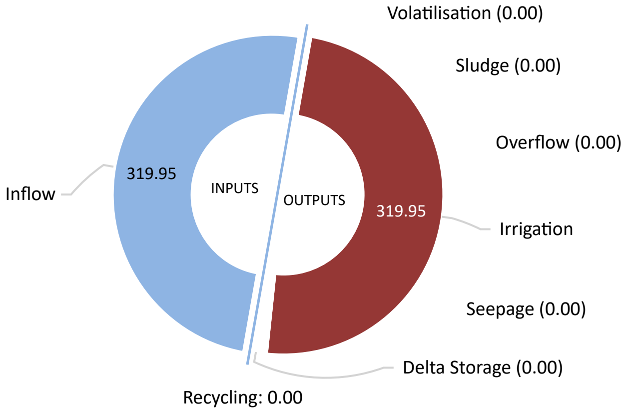
Export plot

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

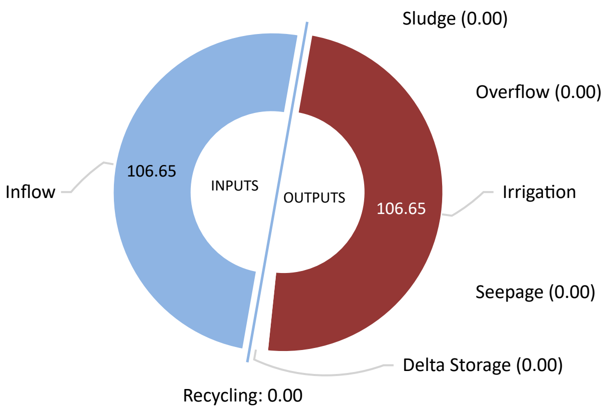
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



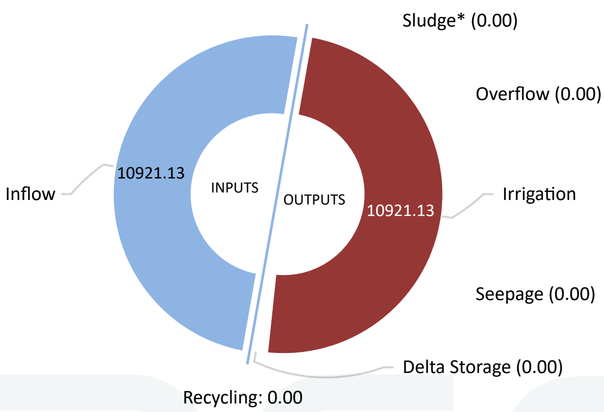
Name	Value
Inflow	319.95
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	0.00
Irrigation	319.95
Seepage	0.00
Delta Storage	0.00

Phosphorus Balance (kg/year)



Name	Value
Inflow	106.65
Recycling	0.00
Sludge	0.00
Overflow	0.00
Irrigation	106.65
Seepage	0.00
Delta Storage	0.00

Salt Balance (kg/year)



Name	Value
Inflow	10921.13
Recycling	0.00
Sludge*	0.00
Overflow	0.00
Irrigation	10921.13
Seepage	0.00
Delta Storage	0.00

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	30.00
Average phosphorus concentration of pond liquid (mg/L)	10.00
Average salinity of pond liquid (dS/m)	1.60

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	30.00
Final phosphorus concentration of pond liquid (mg/L)	10.00
Final salinity of pond liquid (dS/m)	1.60

PERFORMANCE

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (m3/year)	10665.16
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (m3/year)	10665.16
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	30.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	30.00
Average phosphorus concentration of irrigation water (mg/L)	10.00
Average salinity of irrigation water (dS/m)	1.60

Irrigation Diagnostics:

Proportion of Days irrigation occurs (fraction)	1.00

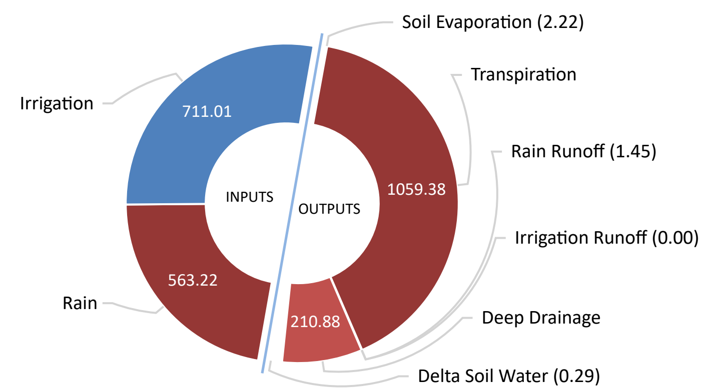
PERFORMANCE

Land Performance - Soil Water

Paddock: New Paddock, 1.5 ha
Soil Type: Sand, 80.70 mm PAWC at maximum root depth

Land Water Balance (mm/year):

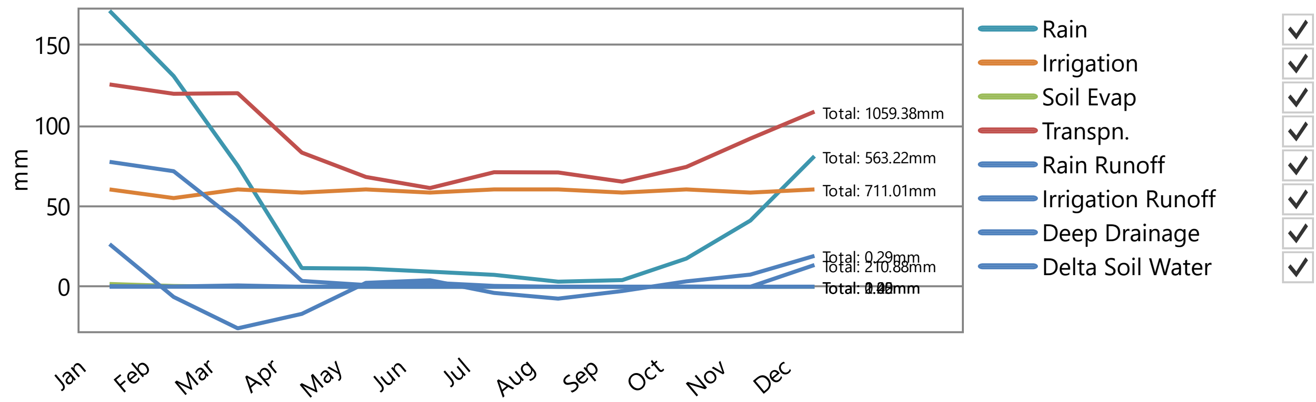
■ mm/year ☐ % Total inputs



Name	Value
Rain	563.22
Irrigation	711.01
Soil Evaporation	2.22
Transpiration	1059.38
Rain Runoff	1.45
Irrigation Runoff	0.00
Deep Drainage	210.88
Delta Soil Water	0.29

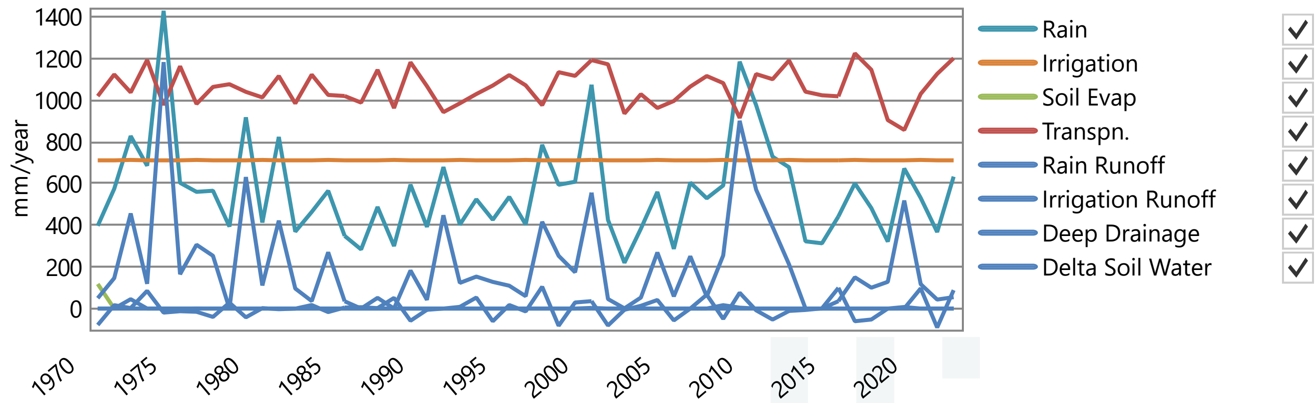
Average Monthly Totals (mm):

■ Chart ☐ Table



Average Annual Totals (mm/year):

■ Chart ☐ Table



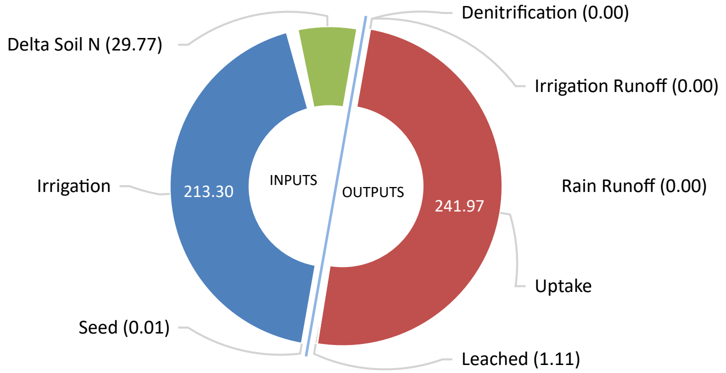
PERFORMANCE

Land Performance - Soil Nutrient

Paddock: New Paddock, 1.5 ha **Soil Type**: Sand

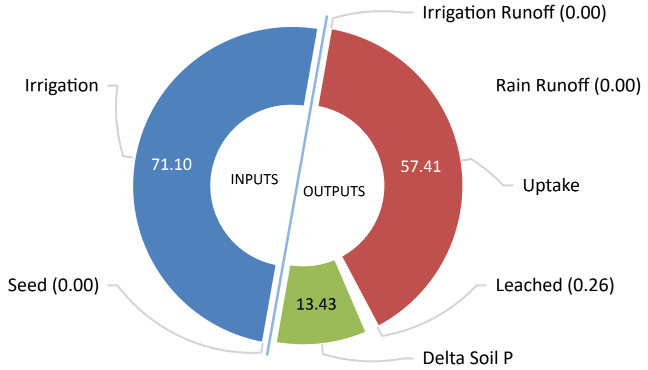
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.10

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.01
Irrigation	213.30
Denitrification	3.59E-03
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	241.97
Leached	1.11
Delta Soil N	-29.77

Land Phosphorus Balance (kg/ha/year)



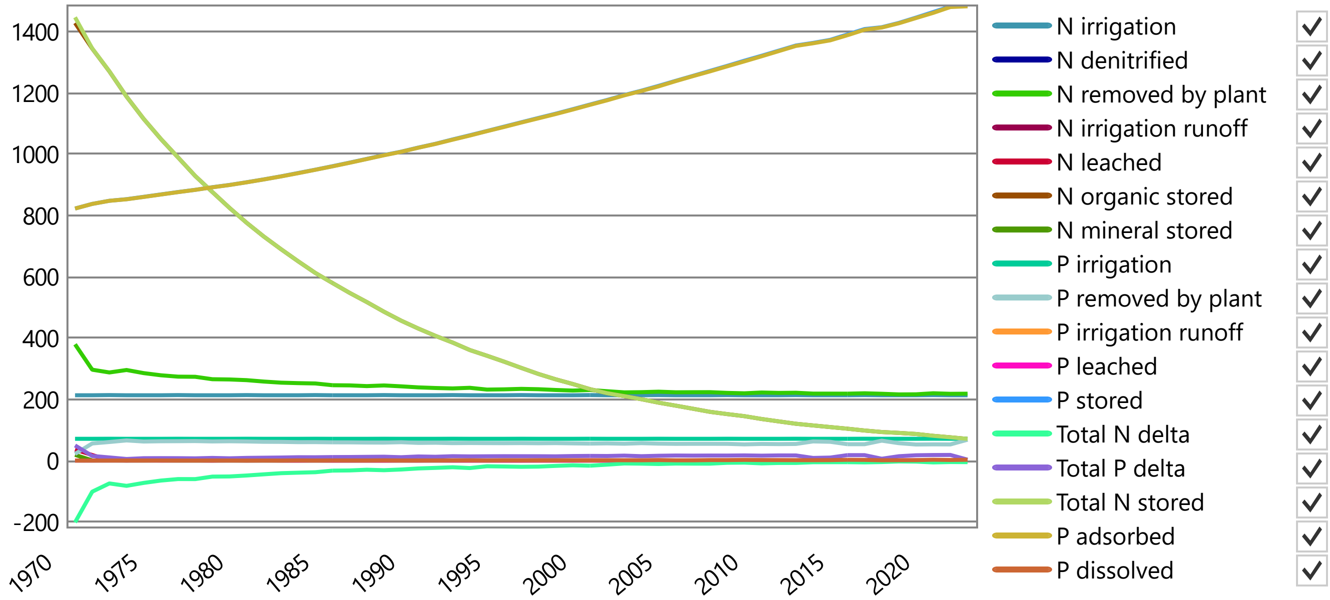
Name	Value
Seed	1.70E-03
Irrigation	71.10
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	57.41
Leached	0.26
Delta Soil P	13.43

PERFORMANCE

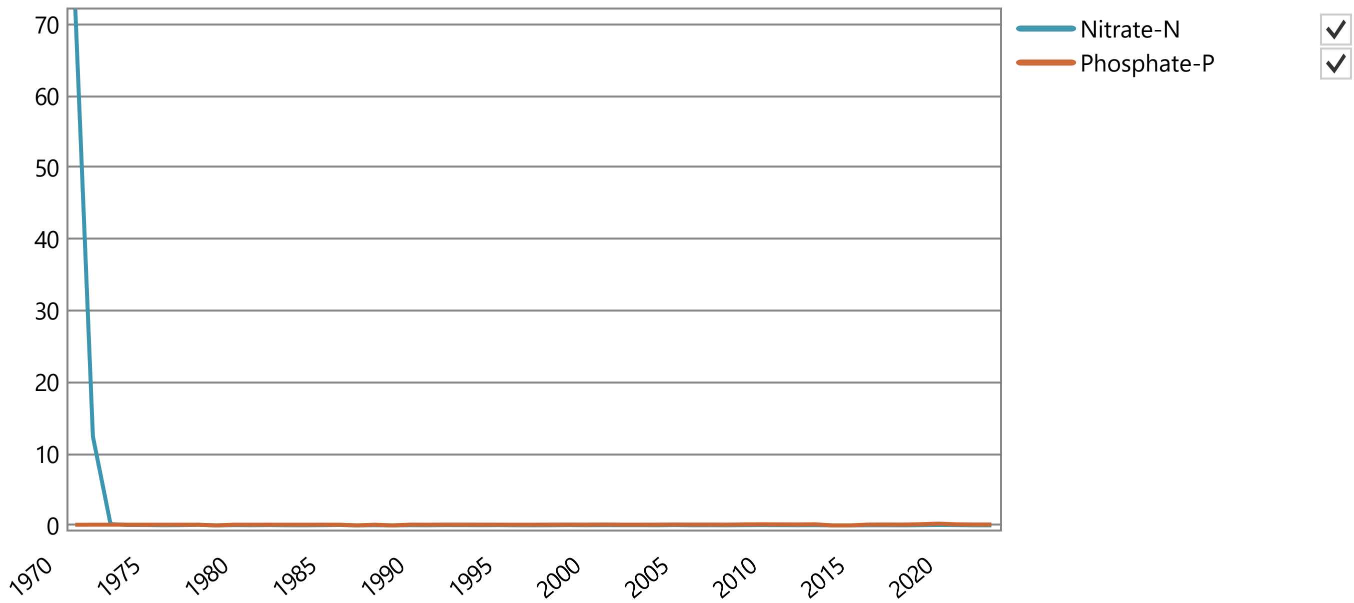
Land Performance - Soil Nutrient

Paddock: New Paddock, 1.5 ha **Soil Type**: Sand

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



PERFORMANCE

Plant Performance and Nutrients

Paddock: New Paddock, 1.5 ha **Soil Type**: Sand

Plant: Continuous Rhodes Grass Pasture

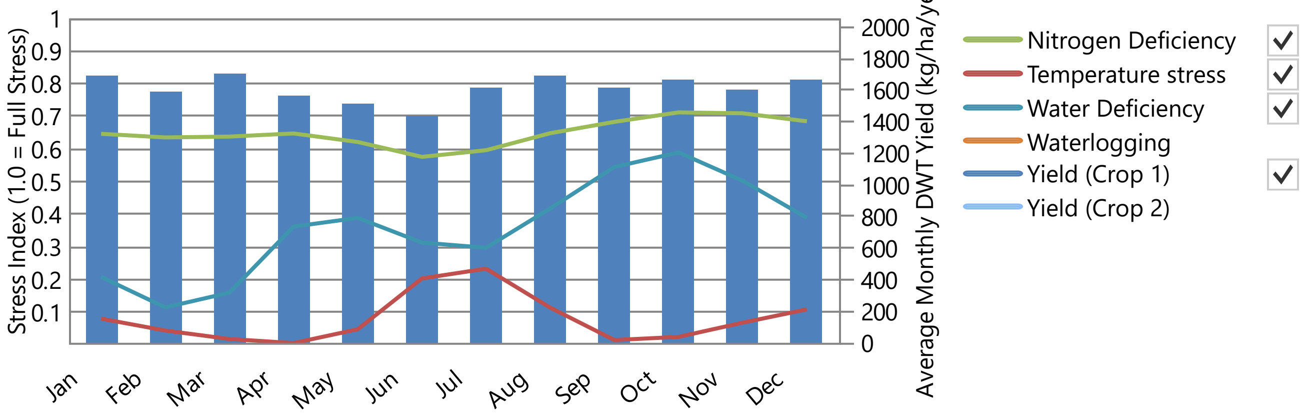
Average annual shoot dry matter yield (kg/ha/year)	19378.76 (17484.24 - 25927.09)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.71 (0.68 - 0.73)
Average monthly root depth (mm) (minimum - maximum)	1198.72 (1186.95 - 1200.00)

Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	241.97 (216.01 - 379.46)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	57.41 (21.75 - 68.03)
Average annual shoot nitrogen concentration (fraction dwt)	0.01 (0.01 - 0.01)
Average annual shoot phosphorus concentration (fraction dwt)	0.003 (0.001 - 0.004)

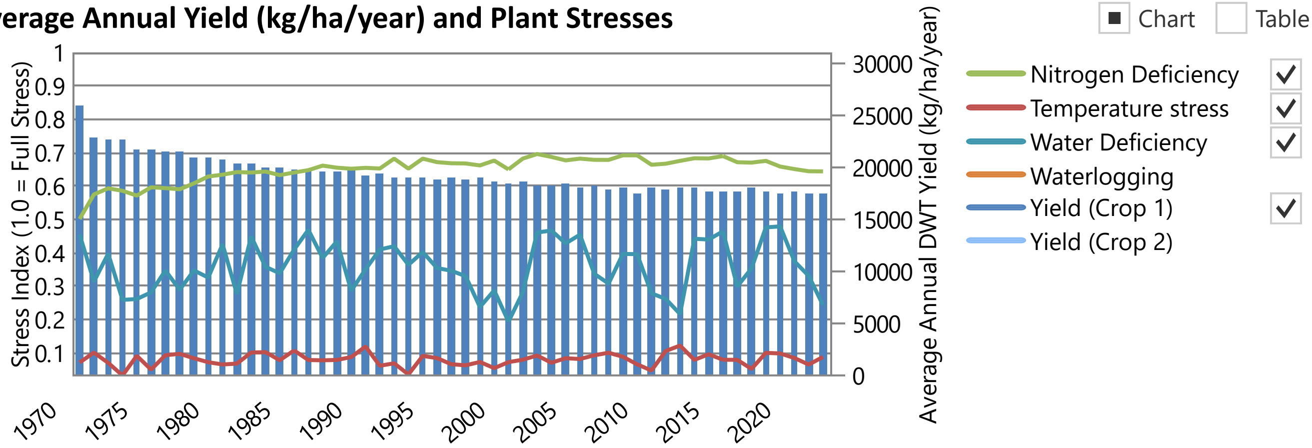
Average Monthly Yield (kg/ha/year) and Plant Stresses

Chart Table



Average Annual Yield (kg/ha/year) and Plant Stresses

Chart Table



No. of harvests/year: 3.38 (normal)

No. days without crop/year (days/year): 0.00

PERFORMANCE

Land Performance

Paddock: New Paddock, 1.5 ha **Soil Type:** Sand

Plant: Continuous Rhodes Grass Pasture

Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03
No. years assumed for leaching to reach steady-state (years)	10.00

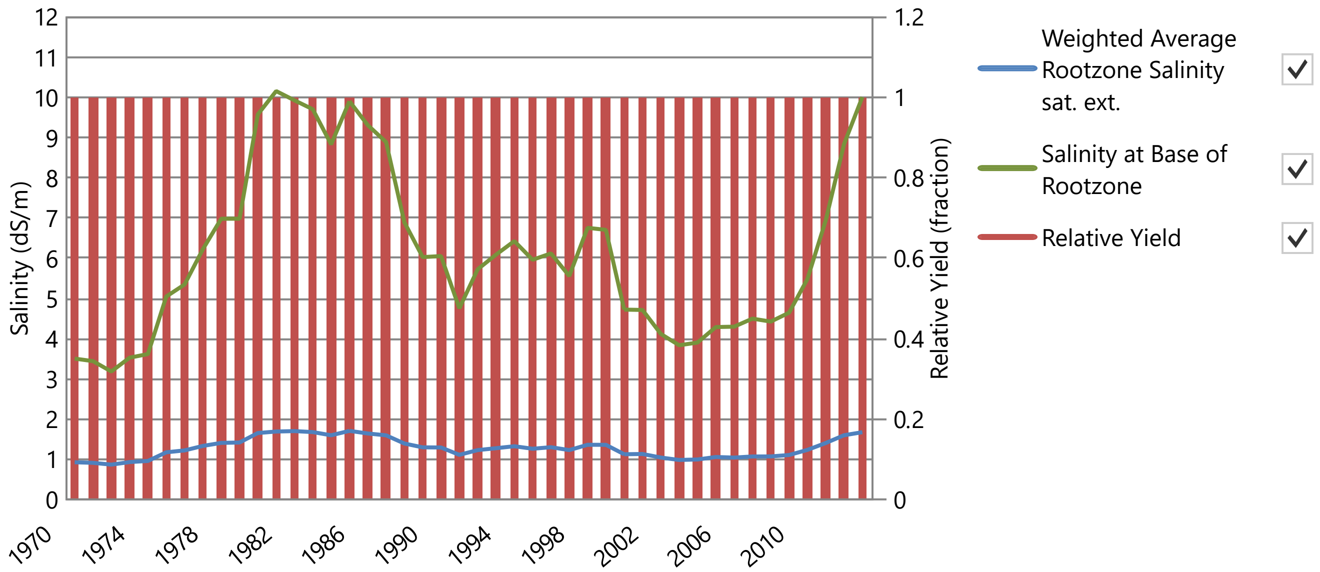
Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.91
Salt added by rainfall (kg/ha/year)	107.86
Average annual effluent salt added & leached at steady state (kg/ha/year)	7388.61
Average leaching fraction based on 10 year running averages (fraction)	0.33
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	1.28
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	6.18
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield:

■ Chart ☐ Table

All values based on 10 year running averages



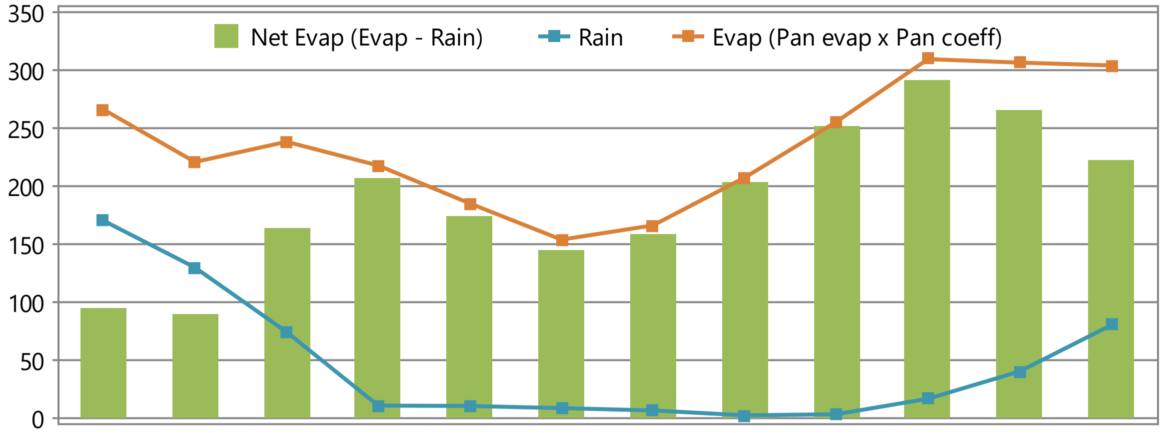
DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Permeable

Averaged Historical Climate Data Used in Simulation (mm)

Location: Vecco Mine, -19.95°, 141.9°

Run Period: 01/01/1970 to 31/12/2022   53 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	171.1	130.6	75.1	11.6	11.3	9.4	7.4	3.2	4.1	17.5	41.0	81.0	563.2
Evap	266.9	221.6	239.0	218.6	185.9	154.6	167.0	208.1	256.3	310.2	307.2	304.8	2840.3
Net Evap	95.8	91.0	163.9	207.0	174.6	145.3	159.6	205.0	252.1	292.8	266.2	223.9	2277.1
Net Evap/day	3.1	3.2	5.3	6.9	5.6	4.8	5.1	6.6	8.4	9.4	8.9	7.2	6.2

DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Permeable

Pond System: 1 closed storage tank

Vecco STP - 10665.16 m3/year or 29.20 m3/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum influent quality calculated for 365.25 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	319.95 (319.74 - 320.62)
Total Phosphorus	10.00 (10.00 - 10.00)	106.65 (106.58 - 106.87)
Total Dissolved Salts	1024.00 (1024.00 - 1024.00)	10921.13 (10913.79 - 10943.69)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

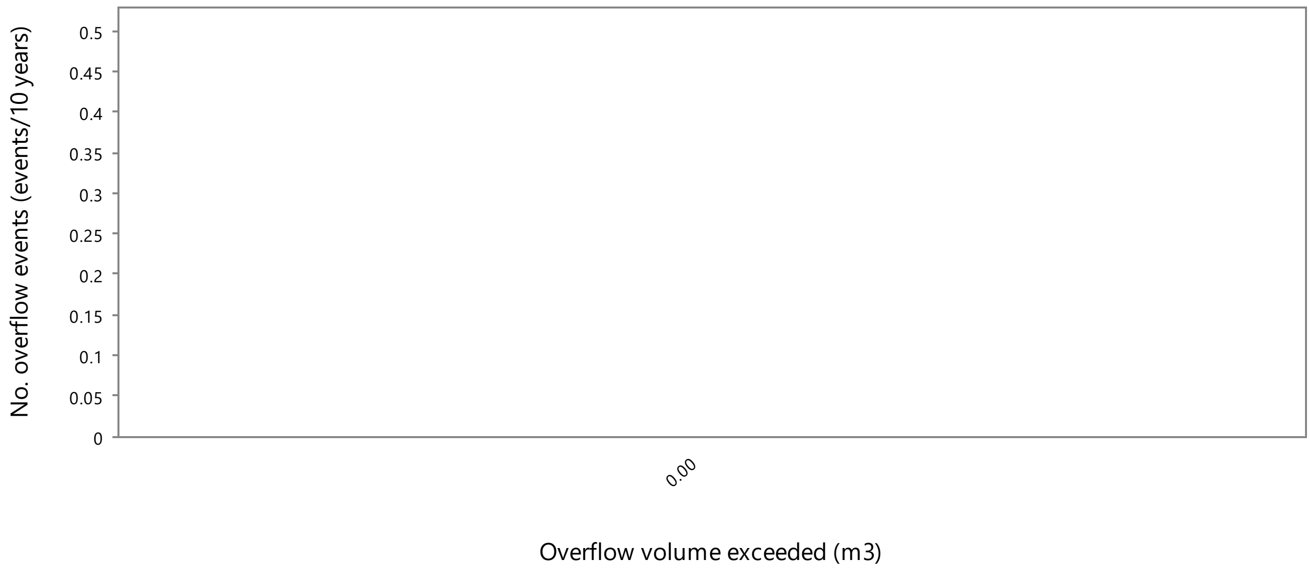
Last pond (Wet weather store): 88.00 m3

Theoretical hydraulic retention time (days)	3.01
Average volume of overflow (m3/year)	0.00
No. overflow events per year exceeding threshold* of 0.03 m3 (no./year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	1.60
Salinity of last pond on final day of simulation (dS/m)	1.60
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

■ Chart ☐ Table



Export plot

DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Permeable

Irrigation Information

Irrigation: 1.5 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (m3)	10665.16	7110.11
Total nitrogen applied (kg)	319.95	213.30
Total phosphorus applied (kg)	106.65	71.10
Total salts applied (kg)	10921.13	7280.75

Shandying

Annual allocation of fresh water for shandying (m3/year)	0.00
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation occurs (fraction)	1.00

DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Permeable

Paddock Land: New Paddock: 1.5 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Irrigation triggered every 1 days
Irrigate a fixed amount of 2.00 mm each day
Irrigation window from 1/1 to 31/12 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Sand, 80.70 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	171.1	130.6	75.1	11.6	11.3	9.4	7.4	3.2	4.1	17.5	41.0	81.0	563.2
Irrigation	60.3	55.0	60.3	58.4	60.3	58.4	60.3	60.3	58.4	60.3	58.4	60.3	711.0
Soil Evap	1.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Transpn.	125.4	119.6	120.0	83.2	68.1	61.2	71.0	70.9	65.2	74.3	91.9	108.6	1059.4
Rain Runoff	0.4	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	77.4	71.7	40.3	3.6	1.1	2.5	0.5	0.0	0.0	0.2	0.0	13.5	210.9
Delta	26.4	-6.3	-25.8	-16.8	2.4	4.0	-3.8	-7.3	-2.6	3.4	7.5	19.2	0.3

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	213.30
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	241.97
Average annual soil nitrogen removed by denitrification (kg/ha/year)	3.59E-03
Average annual soil nitrogen leached (kg/ha/year)	1.11
Average annual nitrate-N loading to groundwater (kg/ha/year)	1.11
Soil organic-N kg/ha (Initial - Final)	1494.50 - 70.78
	154.21 - 0.02
Average nitrate-N concentration of deep drainage (mg/L)	0.53
Max. annual nitrate-N concentration of deep drainage (mg/L)	72.19

Soil Phosphorus Balance

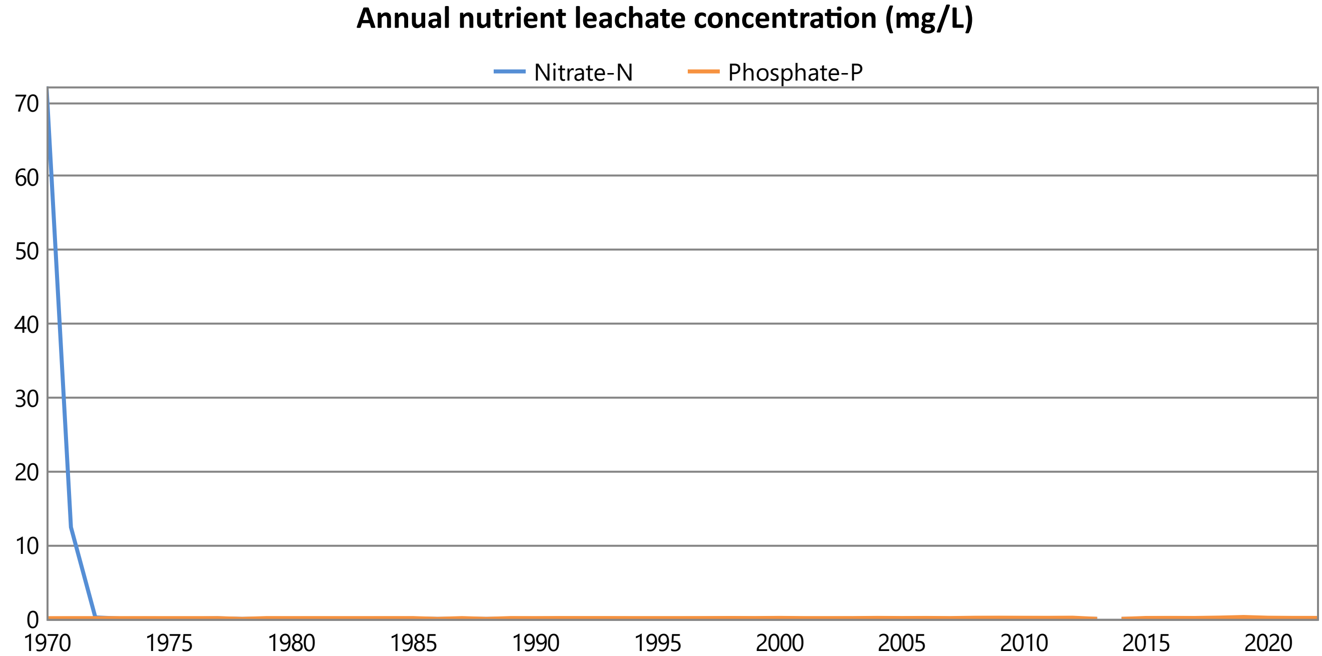
Average annual effluent phosphorus added (kg/ha/year)	71.10
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	57.41
Average annual soil phosphorus leached (kg/ha/year)	0.26
Dissolved phosphorus (kg/ha) (Initial - Final)	0.19 - 2.51
Adsorbed phosphorus (kg/ha) (Initial - Final)	773.25 - 1482.94
Average phosphate-P concentration in rootzone (mg/L)	0.73
Average phosphate-P concentration of deep drainage (mg/L)	0.12
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.25
Design soil profile storage life based on average infiltrated water phosphorus concn. of 5.59 mg/L (years)	30.16

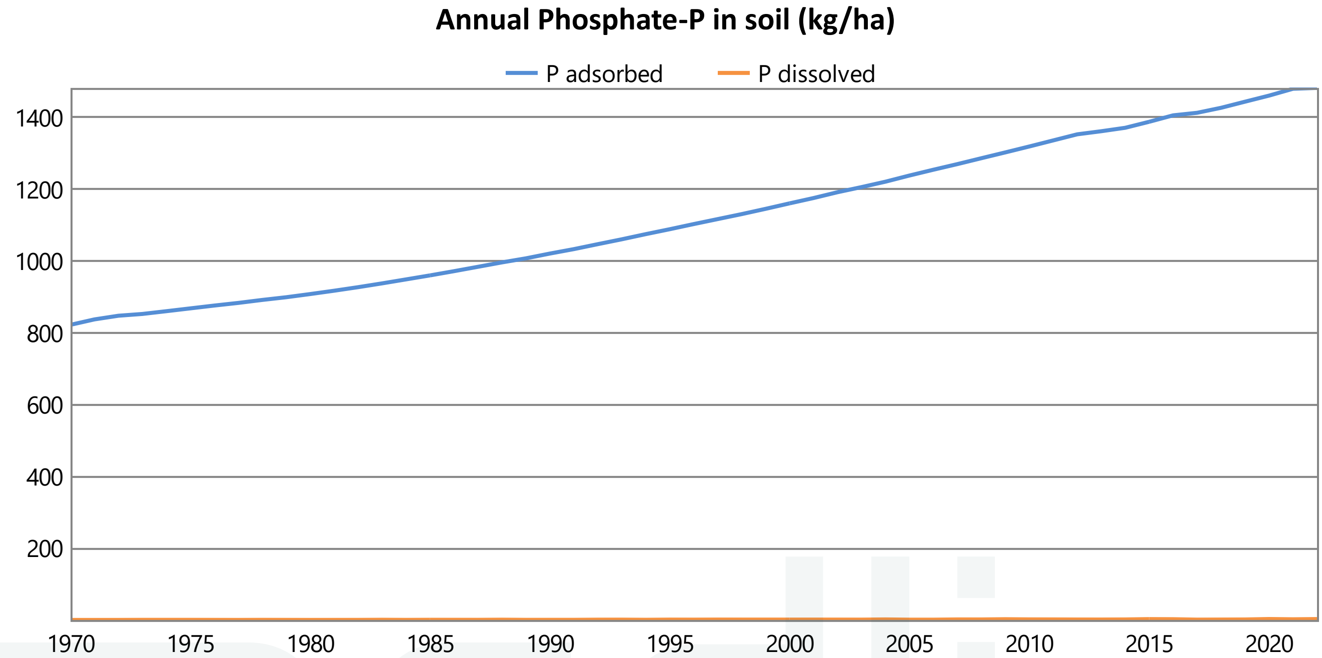
DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Permeable

Paddock Land: New Paddock: 1.5 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation





DIAGNOSTICS

Sustainability Diagnostics: Vecco Mine Extreme Permeable

Paddock Plant Performance: New Paddock: 1.5 ha

Average Plant Performance (Minimum - Maximum: Continuous Rhodes Grass Pasture

Average annual shoot dry matter yield (kg/ha/year)	19378.76 (17484.24 - 25927.09)
Average monthly plant (green) cover (fraction)	0.71 (0.68 - 0.73)
Average monthly crop factor (fraction)	0.64 (0.61 - 0.65)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	1198.72 (1186.95 - 1200.00)
Average number of normal harvests per year (no./year)	3.38 (3.00 - 4.00)
Average number of normal harvests for last five years only (no./year)	3.20
Average number of crop deaths per year (no./year)	0.00 (0.00 - 0.00)
Average number of crop deaths for last five years only (no./year)	0.00
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.65 (0.50 - 0.70)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.08 (0.00 - 0.21)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.23 (0.04 - 0.39)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.36 (0.11 - 0.59)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.00 (0.00 - 0.00)
No. days without crop/year (days)	0.00

Soil Salinity - Plant salinity tolerance: Tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.91
Salt added by rainfall (kg/ha/year)	107.86
Average annual effluent salt added & leached at steady state (kg/ha/year)	7388.61
Average leaching fraction based on 10 year running averages (fraction)	0.33
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	1.28
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	6.18
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

DIAGNOSTICS

Run Messages

Messages generated when the scenario was run:

Full run chosen